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Whole vs. Part Methods in Motor Learning. A Comparative Study

BY

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WHOLE Vs. PART METHODS IN MOTOR LEARNING—A COMPARATIVE STUDY

CHAPTER I.

Nature of the Problem

One of the several problems of the general pedagogical-psychological field that warrants full analysis is the 'whole' vs. 'part' method of learning. Whole method procedure demands the continuous repetition of an entire body of material until the desired stage of mastery is attained. Part procedure requires an initial mastery of definite sections of the material and the final connection of these different sections in proper serial order. This 'whole'—'part' problem loomed large during the past decade, but interest in it seems to have waned, due no doubt to the acceptance of the experimental evidence as final. This evidence was first deduced from the learning of the Ebbinghaus nonsense syllables. This pioneer in the scientific study of memory set the problem. Meumann (11) presents his own work, planned to supplement the splendid efforts of Steffens (19). Ephrussi (4), Neumann (13), Pentschew (15) of the German laboratories, Larguier des Bancels (10) of the French, and Henderson (6), Kuhlmann (8), Lakenan (9), Pyle (17), Pyle and Snyder (18), Watt (21), and numerous other writers in English have investigated the problem. The statements of Meumann (11) may be summarized as typical, i.e., learning by parts becomes more disadvantageous the more the material is subdivided; conversely, the more closely the 'part' learning approximates to 'whole' learning, the more rapidly and certainly is the task accomplished. The learning advantage for the 'whole' method is even greater with meaningful material than with the nonsensical. The superiority of the 'whole' method is manifested by fewer repetitions being required for mastery, more correct formations of associations, and more permanent retention. These results hold for the adult and also for the

child, as soon as the latter becomes aware of the advantages of the 'whole' method. These findings are likewise true for material not constituting a coherent whole. There are possible mediating procedures of the 'whole' method, such as brief resting pauses in the forward directed method or the temporary delay upon parts of obvious difficulty.

The material presented and the evidence reviewed lead to the acceptance of the 'whole' method as the more efficient in the learning of nonsense material and poetry of short lengths. For longer lengths, Pyle and Snyder (18) verified the results for poetic material of 240 lines and Lakenan (9) for prose of 300 words.

Following Steffens, Meumann, Pentschew, and others, the following causes of waste in part learning are, perhaps, suggested, though none of these have been subjected to laboratory testing.

(a) Learning of transitions between units (b) Learning of backward directed associations. (c) Break up of helpful mediate associations and the disturbance of the absolute position assigned to each item during the learning of its own part or section. (d) Lack of uniformity in distribution of the learning. (e) Loss of the aid of logical coherence with sense material.

The above brief survey points to the wide interest the problem has attained and to the strong agreement of the experimental findings. But the interest has not been carried over into the motor field and very few references have been made to the conditions as they would appear in definite class-room situations. Parker (14) is a notable exception. In his recent "Methods of Teaching in High Schools," he suggests that, in the school activities of the gymnasium and shop, in dancing, in musical technique, in the pronunciation of a foreign language, etc., motor control may in some instances possibly be hastened if attention is directed toward the elementary movements involved. Excluding this bare suggestion, the question of the unit ('part') method as opposed to 'whole' learning of the motor act seems to have been disregarded by the experimental

psychologist. Dearborn, Ordahl, Richardson, Swift, Freeman, Colvin, Book, Bryan and Harter, Leuba and Hyde, Ruger, and Thorndike may be mentioned as having either overlooked the problem or else considered the evidence in rote and logical learning so conclusive as to warrant analysis of the parallel motor situation relatively useless.

Summarizing, the following points are descriptive of the work done upon the problem of 'whole' vs. 'part' learning: (a) It has been confined to logical and rote material. (b) Humans have been tested but not animals. (c) The pure 'part' method has been investigated but practically no modifications of it. (d) Greater economy obtains with the 'whole' method. (e) Several proposed explanations of the waste in 'part' learning have been offered, but none of these has been tested under controlled conditions.

The concern of this research, then, may be stated in certain definite propositions:

(1) To see whether the 'whole' and 'part' findings in rote and logical learning hold for sensory-motor, adaptive problems;

(2) To determine whether these laws hold for animals as well as humans when learning conditions are comparable;

(3) To test out certain hypotheses and determine which factors are causative for economy or waste in these methods of learning;

(4) To devise such modifications or combinations as may be better than either of the above methods;

(5) To draw such conclusions from the data secured as may have heuristic and practical values in enforcing or modifying learning conditions imposed upon the school child.

The above program seems to the writer to be timely. The poverty of knowledge of the motor field is obvious. As regards the attempt to determine universality of methods, the comparative psychologist has likewise been dilatory. Barring the research of Hunter (7) upon the Delayed Reaction, the literature fails to show a thoroughgoing attempt to elicit data for humans and animals secured under identical conditions. If the sole excuse for comparative study is to secure information that

will promote the prediction and control of human behavior rather than to gather facts of animal behavior that have a value "in and for themselves", then this research certainly seems opportune. Furthermore, this research makes a thoroughgoing attempt to reduce to a measurable level such obscure terms as the strength of backward directed associations, the learning of transitions between units, etc. Finally, the need for bettering existing methods of learning is always urgent. No doubt criticism may be raised regarding the details of the research. But the writer hopes that his methods will prove stimulating and suggestive to other investigators and that experimentation in an exact and truly comparative sense may be carried out by them. Until the identity of learning conditions is established, any talk of relative degrees of intelligence between different life forms, universality of behavior, etc., seems little short of academic.

In the search for a motor problem where conditions of learning might be as nearly identical as possible for the human and the animal, the maze was selected. The researches of Small, Watson, Carr, Kinnaman, Porter, Yerkes, Hicks, Vincent, Bogardus and Henke, and numerous additional papers, of scarcely less magnitude have served to make the maze problem well nigh commonplace with the psychological experimenter. Perrin (16) continued the work of the Chicago Laboratory with pencil mazes, but the comparative possibilities of his work were not followed up[1] A description of the rat and pencil mazes used by the writer and an analysis of the method of experimentation bring out the comparability of conditions in the present research.

Apparatus and Procedure

A maze of special design was constructed, the details being determined solely for their adaptability to the 'whole' and 'part' learning methods. This maze "A" (page 70) was square,

[1] Since the above was written, Dr. Perrin's (5) article upon the human and child maze reactions has appeared. It will prove interesting to the comparative psychologist to have this valuable experimentation duplicated with the rat.

with a food-box 8″-8″ in the center. The maze consisted of four independent sections, each having its own entrance and exit into the food-box. A distributing gallery around the food-box made it possible by the removal of the panels to learn the sections in any order and to connect them as desired without changing the general exit into the common food-box. Several of the connections are discussed in detail in subsequent passages. The dotted lines (Fig. I, p. 70) show the position of doors and removable panels. It is at once obvious that the sectional arrangements, the conditions of entering and leaving each section, the absolute simplicity of throwing the various sections into a larger motor situation, etc., render this design of immense value for the problem under investigation. The doors and panels were of galvanized iron and worked vertically in slotted brass posts. The posts were securely screwed through the floor of the maze to a 16″-16″ metal plate fastened under the maze floor. The passageways were 4″ in width and height. The partitions were made of ⅜″ stock. Each section contained three cul de sacs, each being 12″ in depth. The final one in each section (immediately preceding the turn to the food-box) was the same in general position for all sections. The remainder of the blinds were differently placed, furnishing four distinct maze patterns. The true pathway for each section was of constant length, 100″. This equality of the four sections in point of number of possible errors and length of the true pathway is partially comparable to logical memory conditions (where verses to be learned are of the same length) and rote material (where the length of the series and its parts are easily controllable). When the parts were thrown together, the total distance represented in the twelve cul de sacs was 48″, with 400″ in the true pathway. The interior walls, panels and doors were painted black. Covering was by four glass frames, the food-box being left open. Sliding panels were attached to the right wall of errors number 3, 6, 9, 12. A rod extended through the outer wall of the maze box and, when this was pulled, it closed the passageway and prevented the return of the rat over the section just traversed.

Such a device made it easy to test the influence of the returns in maze learning.

A second maze (Maze B) was one used by Bogardus and Henke (1). This was used only to verify the results obtained for one phase of the experimentation upon Maze A, namely, the influence of preventing returns. It was unsuited in design for further use. It contained double section alleys, these totalling thirteen single sections. Sliding doors were arranged for blocking returns at the end of sections marked b, d, and h. Consequently, four distinct maze areas are learned but these do not approach equality in number of errors, length of pathway, etc., as in Maze A.

The human mazes duplicated exactly the pattern of the ones just described. They were constructed out of solid brass. The walls were made equal in thickness to the passage-ways, namely, .7 cm. Maze A had cul de sacs 4 cm. in length. The true pathway covered 30 cm. in each section. The entrances, exits, blocking panels, etc, were solid brass plugs, each equipped with a small metal post and fitted into a hole drilled in the maze floor. The plugs were carefully adjusted and never presented rough edges. To the tactual sense, they were parts of the regular maze wall. By adjustment, the sections could be learned in any order and the run modified in the same ways as described above for the animal mazes. Sections could be eliminated without disturbing the general exit into the common open place. Maze B was constructed along similar lines, though without any detail of sectional complexity, since its utility was very limited.

Each brass maze was laid flat on the table when in use and any movement during the testing act was prevented by restraining strips tacked around it. The entire table was covered with a black cloth hood. The subject could move his arm freely under the hood, so that his learning of the maze was unobstructed. His only handicap consisted in being deprived of vision. The hood was open toward the observer, so that the learning efforts of each trial could be observed and recorded.

Animals selected for the experimentation were white rats.

They were secured mainly from the local dealers as needed. Some few groups were bred in the laboratory. No strain selection was attempted. For all the groups, training began at the age of eight or nine weeks. The rats were caged in groups varying from five to seven for a cage and not segregated. The cages were placed on racks around the walls of a 12′ by 12′ room and were never moved from position during the learning period. The rats were fed in the food-box for a period of ten days before the tuition was begun. They were allowed to run at will over the glass top of the maze. They became accustomed to the feeding environment and to human handling. Food consisted of a bread and milk diet, each group being fed in the food-box seven minutes per day following the completion of the day's run. Also, each rat was allowed a nibble of food upon reaching the food-box after each run. The cages were cleaned once per week while the group was feeding. Any disturbances due to changes in bedding, etc., were hereby given opportunity for subsiding during the twenty-four hours intervening before the next trial. During the day, shades to three windows were raised for sanitary reasons. These were invariably drawn when the experimenter entered the room for the day's testing and electric lights were switched on, one occupying the center of the ceiling and directly above the maze, the other a drop light six feet to the rear of the main maze entrance. All testing was done by electric light. One hundred and seventy-seven rats were trained, ninety-one male and eighty-six female.

The human subjects were university students from the writer's classes in Introductory Psychology. Their college classification called for sophomore standing or higher. Seventy-five percent were sophomores. There were fifty-three men and fifty-nine women used for the testing. The testing groups numbered six. Each student reported privately for his test at a period kept constant from day to day. Testing continued at this regular period each day (barring Sunday) until the maze was mastered. No testing was permitted with visitors present. The testing was done in an annex to the experimenter's

office. Constant conditions of lighting, furniture arrangement and quietness were maintained. It is here in order to express thanks to the students for their long-continued and punctual observance of the testing conditions. Without their faithfulness, the results would be vitiated.

Regarding the method of testing, each rat was given one run per day in the maze for four days. Following this, two runs were given in succession per day until four out of five successive runs were without errors. Learning was then considered finished. Time was recorded with a stop-watch from the time the rat turned from the entrance door until he emerged into the food-box. Errors of three types were listed separately. (1) Cul de sacs entered while the rat was going forward. These are called Type A errors. Entrance into a cul de sac was considered accomplished whenever the body was squarely oriented in the error pathway. (2) Cul de sacs entered while the rat was returning toward the entrance, i.e., blind alley errors due to the retracing. These are called Type B errors. (3) Retracing over the true pathway. These are called Type C errors. Such are scored when the rat is returning toward the entrance. Each short section of the return pathway traversed constitutes one such error. During the runs the experimenter was seated back of the main entrance and retained this position, irrespective of the complexity of a particular learning method. The maze box was so constructed that the rat could be placed in the various entry-ways without causing any change in the experimenter's position.

The human subjects were given the same number of runs per day as the rats. The criteria for mastery, scoring of data, etc., were likewise identical. The results of each trial were listed during the run (or immediately following in the case of hurried, almost perfect runs). When the subject was ready for the first run, the experimenter lifted the hand on to the maze area, fixing the stylus in the required locality. The following instructions were then given: "You are now on a surface that has a pathway in various directions. Explore the area, being careful to keep the pointer in the groove and

not allowing it to become dislodged—so! Continue to explore the area until I tell you to stop." No description of this or of any maze was given. No directions as to the types of errors, their avoidances, or striving for speed were given at any time. The subjects were chosen primarily because of their total unfamiliarity with the maze problem. Only after the runner had explored the entire surface and reached the open area, did the experimenter say, "You are now in a large, square area—so! That is called home. You must learn to reach home in the most economical fashion."

It is obvious that the human is forced under these conditions to rely upon contact values for the detection of blinds and the gaining of a sense of direction. Deprived of vision, he is 'sizing' up the novel situation as the rat has been shown to do, a fact ably demonstrated by Watson, Small, Carr and others. In the same stumbling, trial and error fashion he learns the concrete meaning of blind alleys, returning to a closed entrance and the final position that means success. No attempt is here made to state that the mental processes involved in the mastery of the maze situation are identical for the rat and the human. It is maintained, however, that the two have been forced to determine the nature of a situation regarding which they were equally in ignorance and to rely upon the same sensory avenues for data gathering. The satisfying of these conditions is a prerequisite for any comparative study.

CHAPTER II

Comparison of the 'Whole' and 'Part' Methods With Returns Permitted

The introductory chapter has brought out the fact that the maze problem was the one chosen for testing the 'whole' and 'part' procedures. It has been shown that this choice makes possible the establishment of identical conditions of learning for the rat and the human. The identity of the maze problems and the duplication of testing conditions for the rats and humans have been fully set forth. The specially designed mazes have been described at length and their adaptability for testing the 'whole' and 'part' methods commented upon. The present chapter shows how groups of rats and humans were taught the problem by these different methods. Each group is treated separately and its learning behavior and records are displayed below.

(a) Utilizing Maze A, a group of twelve rate, five males and seven females was used to establish results for 'whole' method learning. The behavior of these rats in learning the maze was different in no way from the descriptions generally given. The results of this regular method of maze learning appear in Table II. See page 72.

(b) For learning Maze A by the 'part' method, a group of nine rats, four males and five females was used. The rats were trained in Section I until mastery was attained. As soon as the individual rat had reached this stage, he was transferred to Section II, using of course entrance II and exit II. It has been shown in Chapter I how the learning of a section did not involve any of the other sections, since each section has an independent entrance and exit to the food-box. Upon mastery of this Section, tuition in the remaining units was successively carried out. The behavior in learning the four distinct sections presented no peculiarities, except the readiness with which the

rat began the learning of each new problem. The general hesitancy of attitude was lacking after Section I had been learned. As soon as the mastery of the four units was attained, the separating panels were removed and the rat started at entrance I. The difference in behavior now became marked and was characteristic for the entire group. Starting off at full speed and with almost uniform perfection in Section I, the rat would come suddenly to a halt at the closed door of exit I. Sometimes he would dart back through Section I to the entrance and would return full tilt. A hurried run into Section II produced the same result at exit II. Hereupon the rat's reaction generally went to pieces. Occasionally he might run perfectly into Section II, check his speed, stop, and then return the entire maze length. Retracing, entering blind alleys long since eliminated, pausing, cautionsly exploring the various Sections were characteristic features. Frequent complete returns were made. Occasionally a fresh start and a rapid run would suffice to carry the rat through the entire course. But each rat of the group behaved uniformly respecting the inability to connect the serially learned units, the enormous time lost in retracing and exploring, and the speed of motion. Nor did this confusion subside after the first successful act of connection, as is shown from the data tabulated below. Table I gives the number of trials and the time required for each Section and for the connection of these, together with the errors. Table II gives these results in comparison with the group learning by the 'whole' method. (See page 72.)

These numerical data show an advantage (10%) in the number of learning trials for the whole method, but this is offset by an enormous expenditure of time (118%) and errors made (9.5%)[1] An inspection of the types of errors reveals that the

[1] The attention of the reader is called to the case of a rat of the 'part' learning group, whose records are excluded from the data presented. This rat learned the different units in normal fashion but was unable to connect these. For the first trial, he ran perfectly into Section II, thence retraced until the entrance to Section I was reached. Here he sat for one hour, whereupon he was removed. For this run, he scored no forward going blind alleys. Two were made on the return and twenty-seven re

high number was due to retracing both the true pathway and the cul de sacs. These are more numerous in each case for the 'whole' method (139 vs. 108 for the retrace errors and 24 vs. 17 for the retracing cul de sacs). Much of the great time expenditure in 'whole' method learning occurs in this retracing activity. Consequently, it points out one disadvantage of using the 'whole' method for learning the maze. The problem immediately emerges whether such repetition and time expenditure due to retracing are advantageous. This is seriously called into question, since the only favorable score of the 'whole' method is in the scant saving of 10% of trials. The utility of the returning effort will be investigated in Chapter III.

(c) With the human experimentation in 'whole' method learning, the behavior was identical with the general type as described by Perrin. It agreed also with that of the rats. The early trials accumulated errors of all types. Much time was expended in apparently useless movements into blinds and repeated returning to the entrance. Often the subject would pause as if for reflection and then attack the problem with renewed zeal. See Table IV (page 72) for the results of this test.

(d) In the 'part' learning, the subject was never told when he was set to work upon a new section, yet he seemed to detect the change very quickly. As in the case of the rat, the human worked hard to master each new problem. When the four units were learned, the act of connection gave the same difficulty as was shown by the rats. Some subjects seemed to have a strong determination to go abead but their control over the situation invariably failed.[2] The quickest subject to connect

traces. On the next day he started out rapidly, ran without error into Section II, returned without error to the entrance, where he sat until removed one hour later. He was not run again. He was the single rat of the entire group unable to connect the units.

[2] It is clear that the human subject knew no more of the nature of his task than the rat. He had not been informed that he was to connect four sections that had been learned as units. It was part of his problem to discover this, just as it was with the rat. The writer cannot say whether such previous information would have modified his learning results. Such previous instruction would certainly have rendered comparison with the rat records impossible.

the units required six trials, while the slowest required forty-seven. The records of this experiment are listed in Table III, and compared in Table IV with the 'whole' method records.

This comparison of human records shows an enormous advantage of the 'whole' method and this advantage applies to all the measuring criteria. There is a superiority of 47% for both total errors and time and 48% saving for number of trials. Likewise, this advantage is equitably distributed for all types of errors, since there is a substantial saving for each type when learning is by the 'whole' method.

Comparing the records of the rats and humans (Table V, p. 73), we find agreement in that the 'whole' method brings final success with fewer trials, though with greater percentage of gain for the humans. It is seen that the rats learn their problem with a saving of time and errors by the 'part' method, as opposed to the humans succeeding best by the 'whole'. Yet the 'whole' method is also more efficient for the rats, if the forward going cul de sacs (Type A errors) are made the criterion of measurement. If the retracings were eliminated from the records, the 'whole' method would prove superior in all respects, both for rats and humans. (This shows again the necessity of testing the influence of the returning, especially with the rats). In absolute terms, the humans learn the problem with fewer trials and less time than the rats, both for 'whole' and 'part' learning methods. They accumulate more errors than the rats when the 'part' method is employed, fewer errors with the 'whole' method. This high error accumulation in 'part' learning is assignable mainly to the connecting of the parts. Rats and humans agree in finding this connecting process very difficult, but the humans here require more trials and accumulate more errors of all types, especially of the retracing variety (Type C).

The results of this 'whole' and 'part' testing may be summarized as follows:

(1) Rats. Mastery is attained with a slightly less number of trials when learning is by the 'whole' method. Such learning accumulates more errors and requires a much greater time

expenditure. The errors in excess are not cul de sacs entered while going forward (Type A) but those due to retracing (Type C) and the cul de sacs made possible by this (Type B).

(2) Humans. Mastery is attained with fewer trials, less time expenditure and fewer errors of all types when learning is by the 'whole' method.

It is apparent that additional testing is required to determine the influence of the returning tendency. This alone prevented the 'whole' method from proving more efficient in all cases. If the returns are not counted in the records, it has been shown that the 'whole' method would be better for the rats in all respects, as it had proved with the humans. But it is not justifiable to exclude these returns arbitrarily. Rather, a test situation must be prepared where no more returning is allowed in 'whole' method procedure than in 'part' learning. This is the problem of Chapter III.

CHAPTER III

Influence of the Prevention of Returns

The experimentation reported in Chapter II made clear that the 'whole' method invariably proves superior with the humans and likewise with the rats, except when comparison is with reference to the great number of retrace errors accumulated by the latter. It was shown that the rats probably have a greater tendency to return than the humans, and that this tendency is no doubt exaggerated in the 'whole' method procedure. Logically, it is a question whether these returns are causal parts of the learning process or merely incidental by-products. If they are assisting in the mastery of the problem, they must be counted, both for rats and humans and in both learning methods. It might appear, consequently, that their relative advantage would be different not only for the different methods but also for the rats and humans. It was pointed out that the rats accumulated a high proportion of these errors in 'whole' method learning but that the humans did not. On the other hand, if these errors are shown to be relatively useless, they should not be counted in any case for either animals or humans. The problem of this chapter is to test the influence of these returns.

The equipment of Maze A with sliding panels for the prevention of returns has been described in the introduction. It is, of course, obvious that all returning is not prevented. It is not feasible to prevent all retracing. For our comparative purposes, it is necessary to restrict the returns in 'whole' procedure to the same number possible in 'part' method learning. This demands preventing the return into a definite unit section as soon as this section has been traversed. This effectively divides the whole maze into the four units established for 'part' learning. It renders the amount of returning in the 'whole' method plan practically the same as naturally occurs in the 'part' method.

It makes possible a comparison of the two methods with the same degree of returning. This is exactly the condition desired.

A group of nine rats, four males and five females, was used in this test. As soon as the rat had reached the closed exit to Section I, the return panel was noiselessly pulled. By quietly stepping to the opposite side of the maze the operator was enabled to close the blocks to Sections II and III without distracting the animal from his task of exploration. Often the animals would return to the closed passageway, but the finding of this blocked never resulted in fright or the cessation of the exploring activity. At no time did this group manifest the confusion and random expenditure of energy so typical of the previously described groups. The results of this experiment are arranged for comparative purposes in Table VI.

The returns in the human experimentation were prevented by inserting the tip of a long handled rubber block. This was constructed to fit the pathway completely. It was so held by the experimenter as to prevent any motion if the subject re-explored the area. Because of the general maze direction it was possible to block the returns without getting in the way of the subject. For the first few trials the subject was confused at his inability to return. All knowledge that his pathway had been blocked seemed lacking and he assigned his inability to his own carelessness (see Table VI, page 73).

Inspecting the data of Table VI, its remarkable uniformity of results is manifest. For both animal and human learning, prevention of returns increases the number of trials required for complete mastery, but at an enormous saving of time and errors. So far as regards time and errors, the greater amount of saving is for the rats (151% vs. 18% for time, 95% vs. 56% for errors). With trials, there is 10% vs. 29% increase in number for the humans. Considering the high savings in time and errors and the relatively small loss in number of trials, efficiency as between these types of 'whole' methods rests overwhelmingly with the prevention of returns.

The study of the influence of the returns as a factor in learning was continued with Maze B. This experiment in-

volves the double section alley as contrasted with the single section alley of Maze A. Fourteen rats were used for the unobstructed learning, thirteen for learning with returns blocked. The entire groups were given fifty runs upon the maze, and the records of all the rats for the entire period are combined. These are summarized in Table VII, p. 73. They show for the groups a large amount of saving, both for time and errors.

By the end of the tuition period, 64% of the unrestricted group had mastered the maze but only 54% of the group where returns were prevented. The records of these somewhat quicker learners are abstracted and appear in Table VIII. They show the same time and error saving as do the entire group records. While a larger percentage of the unrestricted had mastered the maze within the alloted period, the average number of trials required is slightly higher. This latter fact is at variance with the parallel results in Maze A. There is no reason to assign this to the difference in type of alleys of the two mazes, or to attempt any explanation, since the results are for a picked group. If, however, the results for the humans upon the same double section maze (where learning was continued until mastery was attained), should contradict the conclusions drawn from the work on Maze A, the question of double section alleys might be raised. Otherwise, it might be concluded that the full completion of the training would produce the results in increased number of trials for obstructed learning as previously stated for Maze A.

Turning to the human learning of Maze B, here again it is found that the entire group masters the problem with less runs when freedom is allowed but that more errors are amassed (Table VIII, p. 73). The restricted group fails slightly to maintain the time advantages generally secured (2.7% decrease), but this and the extraordinarily high number of trials are traceable no doubt to two students of the restricted group, who required 79 and 87 runs respectively for mastery.[1]

[1] The daily records of these two fail to show a continuous fixation of specific errors but rather a general inability to secure a uniform record from day to day. The extreme length of their learning series increased a native tendency to nervousness.

From the data of human and rat learning, both for Mazes A and B and not only for complete mastery but also for a limited number of trials, it seems correct to conclude that prevention of returns increases slightly the number of trials required for mastery but this is accomplished by an enormous saving in time and accumulated errors.

It cannot now be said that the retracing plays no part in the final mastery of the maze situation. Such an answer will depend finally upon maze records where returns are absolutely blocked. The writer is planning the details of such an experiment. He now has in preparation a detailed analysis of the learning of the maze with and without prevention of returns. Here there will be an attempt made to determine the exact value of the retrace error and the retrace cul de sac as factors in mastery. It appears almost conclusive from present data that the retracing and entering into blind alleys, made possible by this retracing are practically useless items. Graphs for the rats learning Maze A show that retracing is a negligible factor long before the first half of the number of required trials has been made; that the return cul de sacs cease to play any part after the first two-fifths of the trials in the case of unobstructed learning and after the first fifth for obstructed; that the forward directed errors are almost identical in number and in distribution throughout the entire learning period and that they and they almost solely determine the learning curve for the last half of the tuition period. (See graphs I to IV). This seems to indicate that the beginning trials are very wasteful when waste is permitted; that the maze is never mastered until the rat finally settles down to the difficult task of forward elimination of errors; that the early trials do not measure learning but primarily the extravagant and useless expenditure of energy. This would argue that the retracing is mainly of no efficiency in learning and hence should be disregarded. If the retracings are eliminated from the records discussed in Chapter II, it is certain that the 'whole' method ranks superior in every possible respect. It was insisted upon in the earlier discussion that the retracings are

the only factors contributing to the high error scores of the 'whole' method procedure, and that such a condition maintained only with the rats. This view is certainly strengthened by the findings of the present chapter. The obvious implications of this are two. (1) It seems fair to question whether the customary practice of including the retracing in the measurement of maze learning is justified. (2) Considerable light is shed upon the advantage of the complete forward direction of effort throughout the entire learning period.

Furthermore, this evidence leads the writer to question the reliability of viewpoint basic to the recent controversial literature regarding the order of the elimination of errors in maze learning. It seems important that the investigators should take into account the big question regarding the influence of the prevention of the returns before any conclusions are drawn in reference to a general eliminative tendency. Again, if true learning is not to be measured by total errors (as suggested above), should the measuring of the alleged eliminative tendency be begun until the stage of aggressive, forward directed learning is reached? This monograph waives any discussion of the order of error elimination, but the topic will be discussed at a later period.

Having tested out the influences of the partial prevention of returns and found that such procedure produces an enormous saving in time and errors, it is in order to compare these results with the statistics of 'part' learning as presented in Chapter II. See Table IX, p. 74, for the data. For both rats and humans, the 'whole' method is strikingly superior. Any question of approximate value for the two methods would rest upon the like number of trials for the rat learning (30 trials for both 'whole' and 'part'). But the evaluation of the two methods as equally efficient is totally unwarranted in the face of the overwhelming decrease of time (13%) and errors (44%). With the humans, this decrease is 26, 126 and 193% respectively for number of trials, time and errors. It is certain, then, that for both rats and humans the 'whole' method in motor learning is to be preferred to the 'part' method, provided unlimited

returning is prevented, or if not prevented, that the return errors are excluded from the data being compared.

The results of testing the prevention of the returns in 'whole' method procedure may be summarized as follows:

(1) The number of trials for mastery is slightly increased, both for rats and humans.

(2) There is a very marked saving in time for mastery and the number of errors is greatly reduced.

(3) The saving in time and the avoidance of errors are assignable directly to the prevention of the retracing.

(4) The forward going cul de sac errors (Type A) are almost constant in number with each method for the same divisions of the learning period.

(5) The retracing is largely useless and should probably be disregarded.

(6) The rat's tendency to retrace is stronger than the human's, but the prevention of returns affects the learning of both in identical fashion.

(7) 'Whole' method learning is more efficient than 'part' learning for both rats and humans, provided no more retracing is allowed than is possible in 'part" procedure.

CHAPTER IV

Elements of Waste in 'Part' Learning

The preceding chapter. has shown that the 'whole' method of motor learning proves superior in all cases, provided no more retracing is allowed than is present in 'part' learning. It is conclusive that the 'part' method fails to secure success with fewer trials, less time consumption, and the accumulation of fewer errors. Naturally, it is necessary to determine the exact factors that create such a condition. Specifically, this means to seek out experimentally the elements of weakness in the 'part' method. Investigators of the methods in the rote and logical fields came to agreement regarding the causes contributing toward making the 'whole' method universally superior. These proposed explanations have been stated in the opening chapter (see p. 2). Two comments need to be made. These proposed causative factors have never been tested in motor learning, nor have they ever been subjected to measurement under carefully controlled laboratory conditions. The aim of this chapter is to test various *a priori* hypotheses and hereby secure a statistical evaluation of their validity. Several of those proposed for rote and logical learning are handled. However, several distinctly new conditioning factors are tested, not only because of their immediate connection with the maze act but also because of their logical reference to learning in general.

(a) Loss due to negative transfer in the learning of the motor units.

Until determined to the contrary, it may be argued that learning one section (one motor unit) exerts an unfavorable influence upon the mastery of succeeding units. While transfer in motor learning has often been investigated, there are no results that show conclusively whether such transfer—either positive or negative—continues unchecked in operation for sev-

eral successive problems. This influence may be so great as to cause an enormous expenditure of learning effort upon the subsequent maze sections. This harmful negative transfer may be the chief factor contributing to the accumulation of the numerous errors in 'part' learning. Reference to Tables I and III shows that this situation cannot be ignored.

Control groups, numbering six for both rats and humans, were taught as a single problem either Part II, III or IV of Maze A. These records denote the normal time required for the mastery of each unit when the learner is free from the influence of a previous learning act. A comparison of these with the records of the groups learning all the four units (the 'part' learners discussed in Chapter II) reveals that successive learning is rendered far easier by previous related activity (See Tables X, XI, p. 74). This positive transfer can be roughly estimated by bringing together our measurements of learning in the formula $T = \frac{(t-t')\ (s-s')\ (e-e')}{t.s.e.}$, where t, s, and e represent the number of trials, time in seconds and errors respectively for the case of original learning and t', s', and e' for the parallelled transfer conditions. The formula thus stated relates the amount of saving to the original learning conditions. Employing it, there is found positive transfer of 43, 47 and 9% respectively for Sects. II, III, and IV in the rat situation, and 2.3, 46 and 70% for the human.[1] Instead of finding an element of waste in 'part' learning, there has been revealed one of its fundamental advantages. Therefore, transfer as an element of waste in 'part' learning of this maze type must be

[1] The percentage of transfer increases with the human throughout the learning of the four mazes. The rat percentage for the fourth problem is relatively a marked decline. This is due to a single rat of the 'part'-learning group requiring 47 runs to eliminate a single error. This raised the group average so high as to allow only a factor of ¼ run to function for the number of trial gain in the formulaic estimation. It is an interesting problem to determine whether transfer should be increasingly favorable in successive mazes numbering more than four and to what limits. The writer believes it obtains certainly for four simple mazes and probably beyond the number. Many factors naturally enter in.

rejected, for transfer is strongly positive and advantageous.

(b) Loss due to disintegration through time.

Considering that the learning effort was distributed from day to day and that the mastery of the individual units involved relatively long periods of time, it appears logical to assign a good part of the great loss in 'part' learning to a mere forgetting of the earlier learned pathways. By averaging the number of days elapsing between the learning of Sections I, II, and III, and the return to these in the final act of connection, there is found a very appreciable time interval. This is fifteen, eleven, and four days for section I, II, and III respectively with the rats and thirteen, eight, and five respectively for the humans.

Different groups of untrained rats were taught a single unit and then allowed to rest for the required time interval. During this interval, the rats were placed daily upon the maze top and allowed to run for one minute before food was placed in the food-box. This furnished approximately the same amount of daily activity upon the maze and gave the rat the exercise demanded to preserve good bodily conditions. Cramped cage conditions necessitate this. At the end of the interval, the rats were retrained upon their respective sections. This was continued until the mastery criterion of four successful runs was satisfied. Hence, the disintegration through time is measured by the relearning expenditure. Human groups were excused from reporting to the laboratory for the appropriate interval. Their loss due to time is likewise measured by the relearning method. Tables XV, XVI, pp. 75-6, present these data. The disintegration is notably small. In fact, nearly all the group members were perfect in retention and the relearning effort was mainly expended by a single rat and some human subjects that had originally learned their problem very hurriedly.[2] It is certain, therefore, that disintegration through time must be disregarded as a waste element in motor 'part' learning.[3]

[2] This was especially true with Rat Number 4 of the Section II group. His original learning required but one trial, with two errors, and 487 seconds. His relearning required seven trials, eleven errors, and forty seconds. This suggests not only the question of relationship between speed of

(c) Loss due to retro-active inhibition.

It has been shown above that learning one motor unit is favorable for mastering subsequent ones and that a unit will not disintegrate during a limited time interval, provided only one such unit has been learned. But are the conditions reversed when the rat is taught several such units? Specifically, do the learning efforts expended in mastering Sections II, III, & IV, impair the ability of running I, II, III, and even the last mastered, IV? The influence of the interval of time under such conditions may logically be disregarded (see section above) but it is mandatory that the control over each sectional pathway be carefully tested. If this control has been broken up by subsequent learning activity, it is obvious that herein rests the explanation for much of the inability to connect the units in the final motor series.

An entirely new control group of rats was trained upon the

learning and accuracy in retention but also whether the maze has ever been learned until the rat has taken time to work it out thoroughly,—either in the original learning or relearning process. There is fundamental difference between knowing how to steer by the unexplored areas (cul de sacs never entered) and knowing the character, depth, and position of these. The writer has never had a rat that did not work out the maze completely, either in the original or relearning situation. Considerable data relative to the learning time and retention accuracy will be published at a later period.

[3] This paper has waived detailed discussion of the question of retention, though the writer heartily agrees that one measure of the efficiency of a learning method is the strength of retention (as Meumann had shown in the case of rote learning). Group records have been accumulated for 'whole' method learners, with and without the prevention of returns, and for eight, seven, and five weeks. No big differences seem to appear for the same time intervals. The accuracy is very high, the loss being in the time of the first several runs in retesting. This is not due to exploration of cul de sacs or retracing but to slow and cautious rate of forward progress. Records for 'whole' and 'part' learners, where there was *progressive* retesting for 1, 2, 3, and 4 week intervals between the retesting (not the original learning) seem again to reveal strong retention, but with a probable time value in favor of the 'whole' learners. This is to be expected, since the final four perfect runs of 'part' learners in the original learning act are invariably slower than for the 'whole' learners. However, the writer regards the retention question in its relation to original learning methods as being practically unattacked in this motor realm.

four motor units, following the exact procedure laid down for the 'part' group. As soon as the individual rat had mastered the final unit, Section IV, he was retrained upon Section I. Such retraining was kept up until the mastery criterion of four successful runs was satisfied. By this relearning method, therefore, the experimenter was enabled to measure the retro-active inhibition exerted upon Section I. Note that entirely different and completely trained control groups would be required for measuring this inhibition on Section II and Section III, provided the single group failed to demonstrate its ability to run not only Section I, but Sections II and III in turn. Table XII, page 75, embodies the data. Inspection reveals practically absolute control of the successive units.[4] Hence, only one group was employed for the testing of all the sections. When the entire group required for the complete relearning of the four sections but an average of .6 trials, 3.9 seconds, and .65 errors per section (with all the relearning effort being directed to one section and herein expended mainly by a single blind rat), it is obvious that retro-active inhibition must be disregarded as an element of the great waste in learning the maze by the 'part' method.

(d) Loss due to contiguity of unit functioning.

It has been shown that learning a section does not interfere with the acquisition of a section on subsequent days (Transfer). Also, it is clear that the mastery of a new section does not interfere with the running of previously learned sections, provided that at least a day interval is allowed between tests. (*Retro-active inhibition*). Finally, all the motor units learned may function perfectly, provided a day or more elapses between the trial acts. (*Retro-active inhibition*). But it is pos-

[4] Attention is called to the fact that Section III alone presented difficulty. This difficulty is almost negligible, since 2.2 errors for a group is of course practically to be disregarded. It will furnish cold comfort to some of the present day animal psychologists to be told that the errors of Section III were made by two rats, the first, *completely blind,* whose relearning effort required seven trials, nine errors and fifty-three seconds, the other, three trials, two errors and fourteen seconds. These two rats alone determine the scores for Section III. If the blind rat were excluded, the averages for the group would approach zero.

sible that two acts might function successfully without any interference between them when there is interposed this considerable time interval, and yet that marked interference might occur if these different motor habits were forced to function immediately in succession, a condition that maintains in the connecting act of 'part' procedure. The difficulty so clearly demonstrated in the connecting act in 'part' learning may consist primarily in an interference resulting from this contiguity of function. The validity of this hypothesis had to be tested, not only in the case of motor acts learned in immediate succession, but for all possible combinations of the total collection of acts at the disposal of the subject.

A new group of rats (six in number), was taught the four maze sections. Retesting was made upon various sections as soon as Section IV was mastered. Here, differing from the group reported in the retro-active inhibition test, each rat was given but one run per section and then changed immediately to one not successively learned. This requires two distinct adjustments. All typical combinations were tested. These, for successive days, were I & III, II & IV, IV & I, III & I, IV & II. These tests of five days produce almost perfect results. In no case did the group average higher than 2/5 errors for the day. Most individuals of the group were able to adjust immediately to any such combinations and to accommodate to these changing requirements day after day. Finally, the daily task was increased by compelling double the general amount of work and this in the inverted order of learning, namely, successive runs in IV, III, II and I. This increasing demand in amount of work and complexity failed absolutely to create a breakdown in control. Three of the rats ran the entire four sections perfectly, each of the remaining three attained a single error for the entire four problems. The scantiness of errors renders untenable any opinion that the 'part' learner does not have control over the specific units he has mastered. This control exists irrespective of the order in which the units are required to function or of their functional contiguity.

(e) Loss due to unit incompatibility in a larger series.

It is logically possible that the various units present inhibitory tendencies one to the other in the act of connection and that these units have to be destroyed before the final act of union can be made. In other words, it needs to be shown whether any motor unit can function as a specific part in a bigger motor situation. Section (d) above merely showed that the units can function in temporal contiguity. It argued nothing regarding whether a definite part of a total act can function independent of that act. Obviously, if a group having mastery of the entire motor situation can run all parts of that situation as parts and various combinations of these parts, the questions of incompatibility of units and their inability to function as parts of a whole must be answered negatively.

The rat and human groups having been taught Maze A in the most advantageous fashion ('whole' method with returns prevented) were tested upon the various parts. (These so-called parts are the four *units* mastered in 'part' learning). By the removal and insertion of panels in the rat mazes and metal plugs for the humans, new connections were easily made possible, yet the character of the parts was unchanged. It was considered essential to try the rearranged parts in the forward learning order and the more crucial condition of inverted learning order. Hence, the subjects were tested in successive order upon I to III, II to IV, and IV to I Maze constructions. Between the completion of each such test, the subject was retrained upon the maze as a whole. This not only tested his ability to add to a modified act all the original parts but prepared him for an equitable attack upon each novel construction.

The behavior in the several changes was typical throughout for both rats and humans. A slowing up of speed at the new junction and an occasional retrace were followed by a headlong dash into the new section. No retracing occurred in the new section. An inspection of Tables XIII and XIV, p. 75, shows the amazing accuracy of both rats and humans in running the sections in variable order. This points to the fact that a motor unit may function as such, *provided it has been mastered as part of a whole.* It shows that no incompatibility as between

specific parts exists in the motor problem. Again, it enforced the conclusion reached in (d), that the sections have no inherent interference when functioning in immediate contiguity. Taken in conjunction with (d), it proved that the difficulty of putting the parts together is because the parts were learned as unit wholes.

From the above series of tests, certain definite conclusions may be stated, these having reference to the alleged causes of waste in 'part' learning. The conclusions apply for animals and humans.

(1) Learning one motor unit does not render the mastery of subsequent units more difficult. Transfer is strongly positive, thus pointing out a clear advantage of the 'part' method.

(2) Practically no disintegration of the motor habit occurs during the time between initial mastery and the final connecting act.

(3) No retro-active inhibition is exerted upon motor habits by the learning of subsequent ones.

(4) Different motor units may function as units in any order. Contiguity of unit functioning fails to disturb the motor habits.

(5) Parts of a motor act present no incompatibility to each other when they are learned as parts of a larger motor situation. They may function perfectly as parts, in any successive combination of parts, or in the entire motor series. Their capacity for part functioning is never lost.

The above generalizations emphasize the necessity of excluding as factors of waste in 'part' learning whatever refers to the mastery of the several units or the interrelationship between these units. By these elimination tests, the writer is led to conclude that waste in the maze problem occurs only in the act of connection and is here traceable almost entirely to the influence of place association. This hypothesis is discussed and tested at length in the following chapter.

CHAPTER V

Place Association and its Relation to Impovement of the 'Part' Method

The universal inferiority of the 'part' method has been demonstrated. Numerous proposed causes of waste in 'part' learning have been tested and rejected. Chapter IV brought out the fact that the writer relies mainly upon place association for an explanation of the poor results obtained by this method.

Place association refers to the definite location of an element of a problem in reference not only to the remaining details of that problem but to the entire environment. In the case of rote learning a certain syllable is learned in reference to its antecedent and consequent (immediate association) and to the remainder of the terms (mediate association). It is hereby assigned a definite position in the word series. This places it in a conceptual scheme. It is located at a definite number of syllable intervals from both the introductory term and the terminal one of the list. It is reached after the same time expenditure in each trial and is followed by a constant time span for the completion of the presentation. Both spatial and temporal factors are concerned in establishing the positional relationships.

In motor learning of the maze type, the establishment of place associations represents a large part of the learning. These associations are no doubt very complex. Certain ones may be indicated. (a) Time. The learner comes to relate a certain time span to a certain change of activity. Specifically, a short time run for the rat means a cessation of the running activity and the substitution for this of feeding. Also, it is logical to suppose that each critical turn or element of the maze pathway is located (though not in a conceptual sense) in the entire time span just as definitely as a term is located in a series of nonsense syllables. (b) Distance. The learner

is taught to run a certain distance and secure a desired change of activity. In the case of 'part' learning, each section requires that the same distance be traversed. Consequently, the learner attacks his daily problem with the expectation of having it solved when certain clearly defined time and distance demands have been satisfied. (c) Details of the maze pathways. Each turn, cul de sac and section of the true pathway become positionally established. A given corner may be located in reference to many factors, e.g., the opening into the food-box, the starting place, the next cul de sac, the electric lights, the position of the experimenter, etc. Each aspect of the course is no doubt associated with and located in reference to all the details of the course and to the entire objective environment as well.

The above suggestions may not be exhaustive. It seems to the writer, however, that they state the main types of place associations that are set up in learning the maze problem. Also, it seems logical to assign the difficulty of the act of connection in 'part' learning to the break up of these specific positional factors. If they are causative of the waste in 'part' learning, the behavior of the learners should reveal it. Again, the evidence drawn from the previous experiments must support the hypothesis. Finally, the factors of place association must be so experimentally treated as to show the exact way they are operating to condition waste. Such a treatment of these factors would produce better learning results than were secured by the pure 'part' method provided the factors are eliminated or negated to some degree. This would demand the devising of improved methods of 'part' learning. The task of the chapter is given to the three necessary lines of procedure stated above.

(a) Behavior.

The behavior of both rats and humans in the act of connecting the successive sections was described in Chapter II. It may be characterized as passing through ten distinct stages. (1) Free and unchecked. When started at the remotely learned Section I, the subject "got his bearings" and proceeded rapidly and accurately. (2) Break down in control. This occurred

at the closed exit to Section I. It is characterized by a cessation of forward directed activity. (3) Testing of old habits. The subject might retrace or dash into Section II. He had learned the meaning of the retracing habit when the pathway was blocked (e.g., in a cul de sac) and also the going ahead habit. (4) Failure of habitual adjustment. Retracing brings failure. Arrival at the exit of Section II (generally the exception for the opening trial at connecting) brings like results. The run through Section II was irregular, wavering, and generally given up, the subject returning to Exit I and then into Section I. This stage is characterized by the development of a strong emotional factor, roughly to be designated as confusion or lack of confidence. (5) Random activity. Here complete inability to handle the situation is manifest. Aimless darting into alleys, incessant complete and partial returns, complete cessation of activity followed by rapid attacks are evident. (6) Directed activity. The subject settles down to the problem, relying not on specific control of units but upon his general maze knowledge. This stage is one characterized by persistency. (7) Accidental success. No less than in the first act of learning, this trial and error process brings the desired result. Judging by the behavior upon the last few sectional passageways, the subject had little, if any, knowledge that he was approaching the desired goal. Following the first successful trial, the subsequent trials suffice for the (8) fixation of the useful movements, (9) elimination of the useless, and the (10) final complete organization of the sensori-motor connection.

The above analysis of the behavior in the act of connection shows clearly the complete breakdown of control. Short time and distance relationships absolutely fail to bring the changed activity previously secured. A specific maze corner ceases to mean a turn "to be followed by food getting." It is now a turn that leads to a new situation, calling for far more time expenditure, more distance to be traversed, etc. The several closed exits represent the critical points where old habits fail. Here the subjects halts, explores the situation, and shows in

every possible way that his control over the motor situation has broken down.

(b) Comparison with previous tests.

It was demonstrated in Chapter III that each unit of the maze could function perfectly as an element. This ability was shown to maintain irrespective of the order of functioning of the several units. This fact argues that positional factors are never disturbed so long as the motor habits are allowed to function as units, but that the connection of these unit habits into a series immediately brings disturbance. It was also demonstrated that elements learned as parts of a whole could be put together in any fashion without difficulty. Such operations did not call for an extension and enlargement of short temporal and spatial relationships. Rather, they represent cases where the subject reaches his goal with less time consumption and less distance traversed than is customary. This difference emphasizes the writer's general contention. It seems certain from these facts that the place associations set up when the parts are mastered have such great strength that they render the act of serial connection extremely difficult.

(c) Experimentation directed toward the elimination of the positional factors.

It is obviously impossible to devise modified methods of 'part' learning where some positional factors (short time acts, short distance traversed, etc.) are not established. No test can be devised to eliminate all these factors at once. It is necessary to eliminate these progressively and in the most advantageous fashion. The tests to be described have value to the extent in which they eliminate or negate to a degree some one or some group of the positional factors. The nature of each new test and the learning will be treated comparatively. A presentation of the learning scores and an appropriate evaluation of each method are reserved until this preliminary survey of the methods and the learning behavior has been made. (See pages 39 sq.)

(1) 'Direct Repetitive'.

Rat groups and humans were trained upon Section I until

mastery was accomplished. At this stage, the individual subject was required to run through the mastered Section I into Section II. This change in the maze pathway was rendered possible by the removal of the dividing panel and the closing of Exit I. When mastery of the I-II course was completed, III was added to the accumulating series, finally IV. In each modification, then, the subject was required to repeat the familiar area and to enter the strange. A review of the mastered sections was hereby given in each trial. Furthermore, the place associations set up during the mastery of Section I were reconstructed as soon as mastery was attained. The problem was made to expand. 'Part' learning called for an isolated attack upon Section II, this and subsequent sections serving very largely to make more deeply seated the short time and short distance factors of each maze unit. The identity in length of the four units argues for this. But by this 'direct repetitive' method, however, the positional factors are no sooner set up than they are made to relate to a larger, more complex situation.

The behavior of these groups was characteristic. Upon finding Exit I blocked, the rat usually proceeded very cautiously into Section II, generally making numerous partial returns to Exit I. Seldom was retracing continued through Section I. The human behaved the same way, but the retracing was probably less marked. Both for rats and humans, there was little or no hesitation after the second trial upon the arrival at Exit I. The same is true for retracing. The entire efforts of the learners seemed directed to the mastery of the final, unfamiliar unit. The speed of approach to this attack was generated by the running of Section I. It shows the operation of a factor roughly to be considered the *influence of the known.* It bespeaks for the method a favorable "warming-up" period. (See Tables XVII & XVIII).

(2) 'Reversed Repetitive'.

Rat and human groups were trained upon Section IV until mastery was attained. As soon as the individual mastered this final unit, he was required to attack the third, working through this into the previously learned IV. In turn, he added on as the first part of the accumulating motor series Sections II and I.

In each modification, then, the subject attacked the novel and ended each trial by traversing the familiar. The problem may be stated as testing the *influence of the unknown.* This method of learning is, therefore, the reverse of the 'direct repetitive' described above. It consists essentially in learning the maze backwards, as opposed to the forward aspect of the previous method. Each trial calls not only for the partial mastery of a new section (the first part of each run) but for the final review of the previously mastered units as well. Both these 'repetitive' methods differ from the 'part' method in the fact that the various sections are not mastered separately. The value of these repetitive methods seems obvious. Place factors never become strongly established. This is doubly clear in this last mentioned method ('reversed repetitive'). Herein the subject has never learned habits of stopping, except at one particular place, *i.e.*, the open door of the food-box. The following paragraph on the behavior in this learning method shows why this is true.

The behavior of these groups differs from that of the 'direct repetitive' type. Usually, after the learning of general maze habits in Section IV, the new problem was attacked eagerly. When the entrance from III into IV was reached (a place where the subject had never learned to stop) recognition with the rats was extremely obvious. Speed was quickened and Section IV run with precision. This general behavior was manifest for all the successive modifications. There was never any stopping at a closed door, for the subject had never made any associations of food getting, changing of running activity, etc., with this. Rather, the closed door meant the entrance to a familiar maze section, one that called for quickened speed and the satisfying of the desired activity at the same identical terminal point. But the recognition cue in the case of the humans failed to function as definitely.[1] (See Tables XVII and XVIII.) Conse-

[1] Maze studies of Carr and Watson (31 and 20) seem to argue for the strength of the kinaesthetic cue as the recognitive agency in the maze situation. The evidence of the present research assigns most of the recognitive capacity to vision. Failure of recognition with the humans may be due to lack of vision. Of course, the question whether the human had reduced the control to the kinaesthetic level is involved.

quently this method fails to score very high with the humans.

(3) 'Progressive Part'.

Rat and human groups were trained in Section I, and then taught Section II as a new problem. Connection of Sections I and II was then required, this being followed by a mastery of III and its addition to the I-II course. A final tuition on IV and its addition to the I-III series completed the experiment. This type of learning resembles the part method in that the sections are learned as definite units. But these parts are made to function as soon as the first two are learned in a bigger, more complex motor situation. The strength of place associations is not continually on the increase, as is the case when four equal units are mastered in pure 'part' learning. Rather, single groups of these positional factors are progressively eliminated. Consequently, the method may be termed 'progressive part'. *The influence of successively learned additions* is hereby measured. Herein the difference between this 'progressive part' and the 'repetitive part' methods is clearly seen. The latter call for a review of the mastered areas in conjunction with the learning of the new. Two types of activity are present. The former method demands either the exploring activity or that different type required for the connection of mastered sections. These cases are quite different. The significance of this fact will be commented upon later in the chapter. Also, these methods relate differently to the positional factors. The 'direct repetitive' method demands a disregard of the place associations set up in reference to the exit of the first short maze section and an entry into an unknown area. The 'reversed repetitive' method calls for an initial attack upon a novel situation, this being terminated by a recognition of and a hurried traversal through the known areas. Little unseating of place associations is demanded. The 'progressive part' method demands a disregard of the place associations as in the 'direct repetitive' case. However, such disregard is far easier because the area to be entered is entirely familiar and is that which has just been mastered. The difference of these three cases is highly significant.

The behavior of rats and humans was strictly parallel. Sections I and II were mastered in regular fashion. The connection of the two presented little difficulty, not nearly the degree manifested by the original 'Part' Group. It was shown in Chapter II that few of these 'part' learners progressed as far as Exit II without errors. (Note that such a group has four units mastered rather than two). In fact, most of the subjects, both rats and humans, effected the connection without errors of any type. The subsequent learning of III and IV and their successive additions follow the description of easy learning just stated for I and II. Certain rats and humans effected the entire series of combining acts without error. The behavior of each subject clearly shows that the elimination of the place associations is rendered very easy by this 'progressive part' method. (See Tables XVII and XVIII.)

(4) 'Elaborative Part'.

This experiment was not planned as an improvement upon the part method but represents one of the happy accidents that occasionally turn up in a research largely directed into the dark. The work was restricted to rats. It is included here for suggestive and not comparative purposes. Also, it throws some light upon the results of the 'modified part' methods just described. The work is here discussed in detail, as it will not be referred to in the subsequent discussion of results (pp. 39 sq.).

The test group of rats was the same as that reported in Chapter IV, Section d. This group had been trained as for 'part' learning except that no act of connection had been allowed. Hence, the rats had command of four distinct maze habits. They were tested upon succeeding days for their control of the units, taking in succession various changing pairs. On the sixth day, the rats were required to run the entire collection of units but in the order directly opposed to that finally to be desired.[2] The extreme skill in doing this has been com-

[2] This complex reviewing of the units in no sense altered the place-association factors set up for each motor unit. Rather, it required the rat to adapt quickly to a change in sensory conditions. It forced him to utilize successively all the motor habits at his disposal. It prepared him to attack any maze situation without delay. In these respects the 'elaborative

mented upon. (See page 26.) Immediately at the close of this IV, III, II, I testing, the rat was placed in Section I and given opportunity of connecting all the parts. The data are recorded in Table XIX. These are itemized for the specific runs given and are complete up to trial four. By the end of this trial the *entire* group had mastered the entire maze. (Trials 2-4 were given the day following trial 1).

Significant comment must be made regarding the connecting behavior. Two of the rats ran perfectly; three entered one blind alley; but continued the journey; one entered one blind alley and returned fifteen sections to the doorway, this being followed by a perfect run. The time of this initial trial was remarkably low (41 seconds). The ability to connect the sections certainly seemed amazing in view of the behavior manifested by the 'part' group reported in Chapter II. The method closely duplicates the original 'part' method. The sole differences are that the unit sections were run in immediate succession as units just before the connecting act, and that there was a review of the parts during the several days just preceding the connecting trial. This is responsible for the great difference in results.

Certain causative factors are perhaps statable.

(a) It may be that there is a slight loss in the ability to control the specific motor habits, this being traceable to the disintegration through time and to retroactive inhibition. But such a loss certainly proves non-effective in causing disturbance when the sections are run simply as units. The general adaptive powers of the organism may prove too weak, however, when the four motor habits are required to function together, and in conjunction with disturbances of place associations. Hence, the 'elaborative part' procedure has its value not in running two or more sections on the same day, but in practicing the various sections separately and hereby eliminating loss. This is a 'practice', a 'warming up', or a 'refreshing' theory.

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part' method differs from the pure 'part' method. The two methods do not differ in so far as the former has specifically eliminated certain of the positional factors before the final act of connection.

(b) The difference between the 'part' and 'elaborative part' scores may be due to place association. In 'part' learning, the rat learns a series of acts,—runs one section; eats food; runs the same section; eats food; removal to cage. This is a unitary series and is completed each day. In the 'elaborative' method, the final procedure is different. Here the series of acts learned is illustrated by the following procedure:—runs Section I; eats food; runs Section II; eats food; etc.; removal to cage. This is wholly different from the series established while mastery of the separate units was being attained. It breaks up this earlier series of acts. This break-up is not so great but that the rat can adapt to it. Yet it is sufficient to make the transfer to the connecting situation (I-IV) far easier. In other words, it might be possible to proceed from four unit sections to linking these without a manifest disturbance, provided such was accomplished by gradual steps.

(c) In linking four units together, positive association must be established. Some connection may be established while the units are being learned, for all the units are parts of a common situation of food, location environment, experience, etc. The act of linking requires a closer association and this is accomplished by contiguity,—functioning in immediate succession. The connecting act of 'part' learning serves this need. The 'elaborative part' method aids the establishment of the final close association by bringing the units together in time and in succession for the first time, and yet in such a way that the distractions which cause errors are not present. The units are first brought together two at a time instead of four, and this proceeding by easy stages is advantageous.

(d) On first thought, the difference in scores for the 'part' and 'elaborative part' groups may be largely due to group differences. This hypothesis is worthless, as the behavior and records of the two groups clearly show. (See pages 11 and 37.)

(e) Some possibility unnoticed by the writer may be explanatory for the difference of results. The above points are merely suggestive and it may be that they are not exhaustive for the situation.

Leaving the speculative treatment of the 'elaborative part' method, there are certain general conclusions that may be drawn from an inspection of Tables XVII and XVIII, page 76, regarding the 'modified part' methods.

(1) For the rats.

The three modifications of the 'part' method all prove superior to the 'pure part' method and to the 'whole', irrespective of the favorable blockage of returns. Superiority is demonstrated by all the criteria of measurement (time, trials, and total errors), except for the total error criterion in the case of the 'direct repetitive' method. Here the total errors exceed the number in the 'whole' method with returns prevented. This difference is no doubt due directly to an allowable retracing (Type C error) in the case of the former method. This exception, however, disappears by making a comparison with the forward cul de sac (Type A) error. The 'part' method and the 'whole' method with returns allowed prove inefficient as learning methods.

(2) For the humans.

One of the modified part methods ('progressive part') proves superior by all criteria of measurement to the 'whole' and 'part' modes of maze learning. The 'direct repetitive' method proves superior by all measuring criteria to the 'whole' method with returns unprevented. However, this 'direct repetitive' method requires more time and develops more errors than the 'whole' method with returns prevented. This difference again disappears by making a trial comparison with Type A errors. Time was lost and errors accumulated by the possibility of returns, as the data show the errors of the B and C type are higher than in the 'whole prevented' method. The 'reversed repetitive' method falls to fifth place and its location is likewise definite for all criteria of measurement. The enormous number of retrace errors (Type C) is due no doubt to failure in recognizing the mastered section upon reaching it. Here the behavior and records differ markedly from the rats and raise the question of kinaesthesis functioning as a recognitive means (see note, p. 34). The pure 'part' method is last in the list, irrespective of measuring criteria.

(3) Rats and humans.

The 'progressive part' method proves universally superior for all types of learning methods. The 'reversed repetitive' is highly favorable with the rat but less so with the human, this difference being statable in terms of recognitive ability. The 'direct repetitive' method is for both groups more favorable than 'part' learning and, in general, than for 'whole' learning (See exception in 2 above). It thus shares favorable universality with the 'progressive part' method. The 'whole' method when returns are prevented is universally superior to the case where returns are allowed in so far as regards time and errors but not the number of trials; in comparison with modified 'part' methods either 'whole' method is inferior. The 'reversed repetitive' method fails to prove efficient with the human, due no doubt to the failure in recognition of the previously mastered sections. The pure 'part' method is the most inefficient method used, waiving a single exception with the rats, this poor result being assignable to the unlimited possibilities of retracing. It is interesting to note that the number of trials, number of seconds, and number of total errors for mastery by a certain method are in absolute terms, universally less for the human than for the rat.

(4) Correlations.

Table XX shows roughly the (a) correlation between the different measuring criteria for all types of motor problems devised. For both rats and humans this correlation is high. It argues that rats or humans manifest high regularity in time and energy expenditure for various motor methods. It shows that there is no royal road to mastery for the human not open to the rat. Also, it shows that correlation is very strong between number of trials and Type A errors, but that this weakens in comparing Type A errors with total time or total errors.

(b) The cross comparison for rats and humans shows that there is good correlation in respect to the number of trials required by the various learning methods for mastery. There is much less correlation when the measurement is in terms of time expenditure or the accumulation of errors. The error measure-

ments show that the highest correlation exists between the Type A errors (forward directed cul de sacs).

The above experiments have been directed toward the verification of the place association hypothesis proposed in the earlier sections of the chapter. They have shown that the positional factors may be so progressively eliminated in various forms of 'part' learning as to render these forms (*i.e.*, modified 'part' methods) much more efficient than the original 'part' or 'whole' methods. At the risk of repetition, it seems advisable to restate certain favorable aspects of these efficient modified 'part' methods.

(a) Progressive elimination of the emotional factor.

Remembering the indecision, random activity, full stopping, etc., of the 'part' learners when in the act of connection, its absence in modified 'part' behavior is significant. With the 'progressive part' method, the learning of Part I and II arouses a complex emotional state which must perforce be overcome while these parts are being mastered. The connection of these fails to re-arouse indecision, fear (with the rats, especially), etc., for the entire course is a known safe one, presenting but a single novel feature, *i.e.*, the connecting unit. This seems to be attacked without bringing any strong emotional accessories. Part III is again a new but relatively less emotion-provoking situation. Its addition to the known course follows the subsidence of the emotional complex. Again, the task presents but a single new feature, comparable to the like feature previously met. The course to be traversed is a longer, but still a safe course. Part IV is learned without arousing to a significant degree any emotional tone whatever and the various motor acts have been so progressively interrelated as to call forth little if any of this emotional disturbance during the final combining stage. In general, the only occasions for the arousal of the complex are during the short task of unit learning (where the state must be eliminated before final mastery) and in the single act of connection (the three successive acts becoming successively easier). With the pure 'part' method, the mastery of each part has called for the arousal and subsiding of fear, hesitation, etc. The task of connection involves, therefore, a re-arousal of the injurious

emotional tone at the three critical connecting points. And the strength of this is cumulative. The connection of the first two maze elements arouses it very little, but the subsequent addition of the remaining section brings very marked disturbance. Neither rat nor human succeeds in avoiding this. The 'direct repetitive' and 'reversed repetitive' methods demand a rhythmic arousal and subsidence of the emotional factor, this having a degree of strength far greater than with the 'progressive' method. It is simultaneously involved in mastering the added unfamiliar section (whether approached from the familiar or leading to it) and in affecting the junction of the two. The emotional complexity logically results in poorer learning scores, an hypothesis admirably supported by the data. However, this becomes relatively less operative for the final additions. In all cases, this complexity is much less than is produced by the act of connection in the 'part' method. It is clear, therefore, that the emotional element, though always present, can be distributed to one or several definite maze points and progressively eliminated. This is impossible with 'part' learning and likewise with 'whole' learning, where numerous tricky, blocking situations are met with for many successive trials.

(b) Progressive elimination of the positional factors.

(1) Temporal. Partially causative of the emotional disturbance are, of course, the time relationships. In 'part' learning, each run has been shown to correlate with a brief time span, this ending with changed sensory conditions of desirability. In learning two short units, the brevity of the temporal series is not so firmly a part of the subjects reacting system as when four had been mastered. Hence, the tendency to stop after running a single unit is more easily modified. Also, the overcoming of this stopping tendency is always followed by success and with utilizing but one, short-time activity. As the accumulation and connection of parts proceed, the successive demands never call for but one such short-time addition. The temporal series progressively increases but always by a definite, short-time, success-bringing act. With the pure 'part' method, the subject knows little beyond a relatively high number of deeply intrenched short-

time acts. The break-up of one of these temporal relationships is relatively easy (though harder than if only two had been established), but this is unattended with success. Neither are the immediately subsequent ones success giving, for only the last and most recently mastered time unit can so function. The demands upon the time relationships are invariably too great. With the other forms of modified 'part' methods, no short-time factor ever becomes strongly seated. As soon as one is set up, it is immediately modified by an addition of like extent. The erection of the temporal side of the final maze situation is progressive throughout. This progression is by stated, constant, temporal units and differs herein from the 'whole' methods. In the latter, theoretically, the final time series is under construction from the beginning of the tuition period. By preventing returns (by cutting the course into four sections), not one but four rival time units of the final total are being constructed, and not only as units but as parts of an indefinite whole. With returns allowed, probably many more such units are set up; having to do with all areas of difficulty of the course. In neither such case, therefore, is the erection of the time series progressively or chronologically made. Temporal habits of stopping are not deeply engendered, but the final series is slow in being attained. It is evident, therefore, that the values of the modified 'part' methods rest in large measure upon (a) progressive elimination of the positional factor of time and the fact that the (b) final time series is successively extended by short regular additions as opposed to an internal adjustment of a constant and highly complex whole.

(2) Spatial.

Spatial factors function in like manner. The position of each section and turn (no doubt especially so for final turns) is mediately associated with the spatial terminus of the run. The last turn means open doorway, food getting, and a complete change in sensory factors. With 'progressive part' learning, relatively few of these are set up by mastering Sections I and II. Those that are indicative of arrival at Exit I do have to be uprooted in the first connecting act. Their poverty of

number is in their favor. Once eliminated they function in the larger series. Each addition to the expanding series calls for a readjustment but this is always directed towards a constant goal, constant results, and over familiar territory. Many of the adjustments are primarily with an unconnected but familiar unit, not internal to the great mass already satisfactorily arranged and now functioning as a unit group. This spatial demand is, therefore, progressively met. With connection of many parts being required, the demands of spatial readjustment obviously are multiplied to a high degree. Suppose each section requires for mastery the establishment of at least two positional factors. Using letter denominations, in Section I are established factors A and B. But logically and empirically these are to have unit functioning, *i.e.,* as AB. Mastery of Section II required the establishment of C and D, but these are reduced to the single CD unity. The immediate connection of the dual AB and CD groups again involves but two adjustments. Section III requires two establishments for E and F, but their reduction to unit functioning requires only two new establishments with the ABCD unity. In short, for the complete mastery of these hypothetical situations, there is demanded the establishment of only fourteen such relational factors. The small number is traceable to the demonstrated capacity of a complex, automatized group to function as a unit in needed adjustments to an external situation. No internal readjustments of great degree seems rationally or empirically needed.

With the 'direct repetitive' method the first section reduces the two adjustments, A and B, to a unit. When this unit adjusts to the new, now-to-be-mastered, C-D situation, the permutations are between three terms, namely AB, C and D. Consequently six adjustments are required to establish the ABCD unit. With the addition of E-F and again of G-H, the adjusting demands remain six for each such addition. This method requires, therefore, a total of seventy such spatial positional attainments. The same number holds for the 'reversed repetitive' method. In both cases, the demands of read-

justment of the spatial factors are successively met. The demand is initially never high and it becomes increasingly easy. Yet these 'repetitive' methods always require a greater number of adjustments than the 'progressive part' methods and the character of these adjustments is more complex. This increase in complexity of character depends mainly upon the demand for a triple accommodation (*e.g.,* AB with C and D) as opposed to a dual demand (*e.g.,* AB with CD).

The spatial complexity in the remaining methods is obvious. In 'part' learning, the four units require a minimum of eight positional establishments. When each pair is reduced to a unit and thrown into the connection series, the four units functioning without errors require twelve combinations, bringing a total to equal either 'repetitive' method and to exceed the 'progressive part' by 43%. But even this numerical equality is deceiving. The permutations are not in reference to single successive functional units but to remotely successive as well, and both forward and backward in direction. Rationally, then, the task is hard. Empirically, the ability of units to function as a whole is destroyed. A veritable dissociation of component maze elements takes place. The subject, having had the mastered groups broken up, begins the new and highly complex task of erecting a bigger, positional series out of the wreckage left him. The maze records show that he does this little or no better than if he had had no earlier sectional training. (In the case of the rat, the group seems almost the worse for the training. Tables I and VI reveal that the connecting act required almost the time of, and accumulated more errors than, 'whole-prevented' learning. Tables III and IV show that conditions were even more disturbed for the human, even in the 'whole-allowed' case). In 'whole' learning, with all eight A-H establishments simultaneously in demand, fifty-six combinations are needed. In the 'whole-prevented' method, the same number is required, but the arbitrary cutting of the maze into four sections may tend to reduce sectional pairs to relatively early and complete unity. This has its reward in the saving of errors and time. This possible economy is spent with 'whole-allowed'

learning in setting up the numerous far-distant and backward directed associations.

It appears, therefore, that values of modified 'part' methods in comparison with pure 'part' and 'whole' methods are statable mainly in the progressive and distributive handling they furnish to the positional factors, whether these are considered as emotional or in more objective forms of time and space. Such conclusions have apparent justification in logical, mathematical, and empirical sources. They argue that the relative advantages of the various 'part' methods must be due mainly to the degree in which place associations are obviated.

The results of the employment of modified 'part' methods for the elimination of place associations may be summarized as follows:

(1) The behavior in the act of connection, the conclusions drawn from previous tests, and the data secured by utilizing modified 'part' methods show that place associations render the act of connection in 'part' learning extremely difficult.

(2) These injurious place associations are statable in both the temporal and spatial series.

(3) Modified 'part' methods are originated which eliminate or negate to a degree some of the harmful place associations.

(4) These modified 'part' methods prove far more efficient than either the pure 'part' or 'whole' methods. This is true for rats and humans.

(5) These methods have been named the 'progressive part', 'elaborative part', 'direct repetitive', and 'reversed repetitive'. The relative values of these vary for rats and humans. Differences are statable in terms of the recognitive capacity.

(6) The value of these methods consists mainly in the progressive and distributive handling they furnish to the positional factors.

(7) There is no royal road to mastery for the human not open to the rat. Both rats and humans manifest high regularity in time and energy expenditure for various motor methods.

But the question immediately emerges regarding the superiority of these 'modified part' methods over the universally

efficient 'whole' method. The partial elimination of the positional factors set up in the mastery of the separate maze areas not only improved the scores secured in 'part' learning, but produced results far superior to those of 'whole' method learning. If these positional factors had been entirely eliminated, it looks as though the results should merely have equalled those secured by the 'whole' method procedure. But the universal superiority of certain of the 'modified part' methods argues at once that there are certain inherent values to 'part' procedure. A further analysis of these part learning methods must be made, with a view to ascertaining their inherent advantages. Such an analysis is attempted in the following chapter.

CHAPTER VI

Elements of Advantage in 'Part' Learning

The results of the preceding chapter are highly significant. It has been shown that 'modified part' methods can be devised which prove far superior to the pure 'part' method of learning. The improvements produced by these new methods have been shown to depend partly upon the progressive and distributive handling they furnish to the positional factors of the temporal and spatial series. But a result of far greater significance has been obtained. These 'modified part' methods prove superior to the 'whole' method, even when this latter method is operating under the favorable condtion of blocked returns. From a logical viewpoint, this result seems improbable. A method which obviates some of the weaknesses of the 'part' method (*e.g.*, place associations) should produce scores that approach the results of 'whole' method learning as a limit. If place associations were the only differential aspects between 'part' and 'whole' method learning, the 'modified part' methods could never excel the 'whole' method. Indeed, the impossibility of devising any modifications of the 'part' method that do more than partially obviate some of the injurious place associations is frankly acknowledged by the writer. It is clear that there are factors operating in 'part' procedure, which are producing the remarkable scores.

The fact that learning scores are inferior under the 'part' method must not blind the reader to the significance of its advantages. These favorable factors may have been operating and yet been apparently submerged by the demonstrated weaknesses of the method. Again, the conclusions long ago reached regarding the learning of verbal material must not blind the reader. The investigators in this field showed the inferiority of pure 'part' learning, as has the present research for the motor field. But none of these former experimenters have

attempted to modify the connecting act. No one has been in a position, therefore, where he was forced to recognize the fundamental advantages of any 'part' method. Such a recognition logically depends upon empirical findings similar to those of the writer, namely, that modifications of the 'part' method not only equal the 'whole' method in efficiency but prove far superior to it. The writer is not arguing against the present conclusions regarding verbal material. He is merely pointing out that there is an angle of the problem not yet faced by the investigators, and showing the conditions in motor learning that make such an issue seem vital.

There seem to be certain obvious advanatges to any 'part' procedure in maze learning. These operate to produce learning scores superior to 'whole' method results.

(a) Transfer.

The present work of the writer has presented definite data regarding the maintenance of transfer. (Chapter IV, pp. 22-23.) The formula for its estimation takes account of the trials, time and total errors and gives a mathematical result that is easily interpreted. The results tend to show that transfer is progressively increasing through the learning of four successive maze habits. (See previous conclusions, p. 22.) If the formulaic estimations are made for the successive stages of the 'modified part' methods, the same conditions of positive transfer are again seen to operate. The conclusion is that subsequent maze habits are mastered far easier than the earlier ones.

Two questions immediately emerge. (1) What are the transfer items that render successive maze habits more easily set up? (2) Do not these operate when the maze is being learned as a whole? Does the learner fail to master the final sections of the maze (specifically, the final three quarterly divisions) with a progressively decreasing energy expenditure? The writer can do little more than speculate regarding the answer.

(1) Transfer items in learning successive maze habits.

General. By general transfer is meant that there are certain habits or attitudes that can function unimpaired in any new

maze situation. These general items refer in no sense to the details of the new maze pattern, but solely to the general character of the problem. Chief of these is probably the *general maze habit.* Several definite elements are involved. (x) Retracing. The dominance of the familiar has often been commented upon. The return pathway is known to be safe. The rat seems natively inclined to return to the closed entrance. Final maze mastery means the complete elimination of this retracing. Learning any maze—long or short—actually inhibits the retracing tendency in subsequent maze learning. (y) Knowledge of the nature of errors. A single maze mastered suffices to teach the learner the concrete meaning of the blind alley. A cul de sac ceases to be a detail that must be cautiously explored. It comes to mean a condition that must be left as soon as possible. (z) Sense of direction. Some learners have almost a "going ahead" instinct. Others become hopelessly confused when leaving a blind alley and learn only through repeated trials to make the turn that leads away from the closed entrance. In subsequent mazes, the truly sophisticated learner will enter the cul de sac, but will proceed along the forward pathway when he returns to the true course. These three elements are fundamental in the development of a general maze habit.

A second item of general transfer is *consciousness of power.* A maze learner spends many minutes in apparently aimless wandering. Hesitation, ceasing to explore the blinds, pausing to wash and rest, etc,, are indicative of the rat's indecision and lack of confidence. Even the human will argue his inability of getting through his first long maze. Nor does this lack of confidence become eliminated after the first successful trial. For many days the task is an arduous one and is approached with hesitation. With subsequent mazes, however, the consciousness of power is clearly seen. No 'warming-up' period is needed. There is no delay at the entrance. Work has come to mean invariable accomplishment and reward. The entire attack upon the new problem is aggressive. The learner has learned to do by previous doing.

Clearly associated with the above is a third general item, namely,—*proper emotional attitude.* It has been shown that a harmful emotional complex arises when the learner is first introduced to the maze situation and again when he is required to connect small maze units. It has been shown that final success cannot be attained until this attitude—a mixture of fear, indecision, curiosity, and perhaps anger—has been eliminated. In its place comes an attitude strongly conducive to success. Confidence, elation and hope may be descriptive of this. Irrespective of anthropomorphic criticisms, the writer is content to believe that the maze learner—animal as well as human—does attack the second maze problem with an entirely different and far more beneficial attitude from that which maintained throughout almost the entire first learning period.

Specific. By specific transfer is meant a certain definite maze habit that can function partially or unimpaired in a new maze situation. The writer is referring directly to the details of the maze patterns. Certain ones may be commented upon. If the first maze has taught the learner that a long run is to be followed by a turn to the right rather than to the left; by a turn of 180 degrees rather than 90; by a sharp, cautious turn of 180 degrees rather than a wide, safe turn of the same type, in so far as the second maze possesses like elements, specific transfer will tend to operate. A concrete example of this is found in Maze A used throughout the experiment. Cul de sacs numbered 3, 6, 9, 12 were constant in location for the four distinct maze units; were all approached by making a turn to the left; were each met with after the same time and distance factors had functioned; were the third and final cul de sacs for each motor unit. (See Figure I.) When the maze was learned as a whole, each of these errors was frequently made. Nos. 6, 9, and 12 (the final error) were especially numerous. In learning the four maze sections separately and successively (as did the 'part' learners), nos. 6 and 9 were rarely entered and no. 12 practically not at all. The maze had been designed with a view of establishing a partial identity of detail for the four sections, so that this element of specific

transfer might be partially tested. The present evidence, though limited, seems to argue for the transfer of this specific motor item.

General elements of transfer probably do not operate at their full value until the third or fourth maze is being mastered. It seems to the writer that they should progressively increase in strength to a maximum and thereafter remain constant. Specific elements of transfer probably operate differently. With an increase in number, these specific elements probably tend to generate an inhibition when later motor units are being mastered. No rule can be stated, but it seems to the writer that specific transfer should increase to a maximum (probably during the learning of three or four simple maze habits) and thereafter should operate with a progressively decreasing valency, even to a negative or harmful level. Controlled laboratory testing may refute these mere theories, and also the rough analysis given above of the transfer qualities. Certainly nothing beyond mere speculation is here proposed. The hope of the writer is that some experimenter will set to work to isolate the transfer qualities, both general and specific.

The above sections have been concerned with the principles of transfer that operate in rendering the second or subsequent maze habits more easily set up. Now, in that both 'part' and 'modified part' methods of learning call for the mastery of new problems after one or more related ones have been learned, it follows that the transfer factors can operate to their fullest strength when learning is by some part method. Transfer is fully utilized when the maze problem is broken up into unit sections. This is a great element of strength in any part procedure. But does this argue that these same transfer effects fail to operate when the maze is learned in toto? If not, a transfer hypothesis will fail to explain why 'modified part' methods produce better results than the original 'whole' procedure.

(2) Transfer in 'whole' method learning.

General. Adopting the analysis given above as truly descriptive of transfer qualities operating in 'part' learning, it is nec-

essary to see if these operate when a large maze is being mastered as a whole. First for consideration is the *general maze habit.* (a) Retracing. This is one marked characteristic of 'whole' method learning. By many partial returns and many frequent ones for the entire length of the return pathway, the subject finally learns that the retracing must be discontinued. Yet this retracing may continue until the last four successful runs. Chapter III brought out the fact that this retracing is probably useless and even harmful. The 'part' learners are forced to inhibit retracing when their problem is simple and when the retracing cannot take much time and accumulate many errors. They master this aspect of the general maze concept under simple conditions, the 'whole' learners under complex ones. Also, a knowledge of the uselessness of retracing gained through the earlier section of the entire maze fails to prevent retracing in the final maze areas. With Maze A, the greatest amount of retracing (after the earlier trials) was from the terminal point of the third division (the end of Section III) and error no. 10 in Section IV. With Maze B, the greatest tendency was to enter the final cul de sac and to retrace therefrom. It appears conclusive that 'whole' method learning fails to make full use of the general non-retracing concept in the final areas of the maze. 'Part' method learning is exactly opposed to this condition, for the final motor units are learned almost without retrace errors. (Tables I and III.) (b) knowledge of the nature of errors. The earlier sections of the total maze suffice to develop this concept. Were it not for the emotional complications, the latter sections of the maze could be run with increasing skill, just as if the areas were being mastered as successive parts. (c) Sense of direction. Here, again, there is no logical reason why the subject should not have learned in the first part of the maze which of the two possible turns from the cul de sac meant a return direction. Fear, hesitation, etc., are leading the runner to take the return pathway, however, so that the transfer values are not allowed to operate.

In the second place, the *consciousness of power* is almost

ineffectual. For many succeeding runs both the rat and the human proceed cautiously. Aggressive attacks come only with experience. And until the maze is almost mastered, a high initial speed will die down long before the final areas of the course have been reached. In 'part' learning, these final areas are mastered with great speed, but here the 'whole' method learners are the most tardy. Many acts of short duration, followed by desirable changes in activity, develop this needed consciousness of power. An act of long duration, carried out through many difficulties, develops this feeling after the time for its greatest utility as a learning tool has passed.

Regarding a *proper emotional tone,* it has been shown earlier that 'whole' method learning involves fear, hesitation, etc., throughout almost the entire learning period. This is naturally accumulative, as has been made clear in earlier chapters. Even when fear is almost eliminated, any disturbing factor, *e.g.,* a slight noise, will cause this injurious condition to operate again. The entire run may be affected. This disturbance often fails to subside for many days. The 'part' learner rarely if ever manifests such instability after one short maze has been mastered. So it seems as though no favorable emotional tone can operate as a transfer element in a long maze, because of the very complexity of the course and the many pitfalls and surprises involved.

Specific. The writer has little to say regarding specific transfer in the entire act. However it may have tended to operate, it seems unable to do so to any great degree, this fact being traceable mainly to the operation of injurious emotional conditions. For example, the duplicated cul de sacs—nos. 3, 6, 9, 12 in Maze A show far greater frequency in 'whole' method learning than in 'part'.

In summary, the writer is convinced that neither general nor specific elements of transfer can be utilized to any high degree in learning a complex motor problem when learning is by the 'whole' method. The demonstrated ability of these transfer items to operate at their full value in 'part' learning seems to the writer to be unmistakable evidence of the advantage of

'part' procedures. This, taken in conjunction with the progressive elimination of the positional factors established in 'modified part' learning, goes a long way towards explaining the favorable results obtained by the 'modified part' methods.

(b) Learning effort and length of material.

An additional aspect of learning a motor problem by short stages needs to be considered. The relation between the learning effort and the length of material needs to be known. Is there a law of diminishing returns operating that makes a long maze more than twice as hard to master as one only half the length? Data are at hand to answer the problem.

It has been shown that the units of Maze A are, in number of cul de sacs, length of true pathway, etc., exactly equal. Consequently, each of these is an equal fourth of the entire maze. No better motor situation could be desired for the comparison of learning effort and length of material. Even series of nonsense syllables furnish scarcely more equitable bases for comparison. The lists used are made equal in length and supposedly in difficulty. Roughly, the short maze sections seem to satisfy the same conditions. Even though these sections may differ in difficulty (as measured by the learning criteria), a comparison of each of them with the total maze will give results highly valuable. It is logically necessary to make this comparison for the entire four, since they are integral parts of the total problem under consideration. The three learning criteria may be brought together in the following formula, $\frac{t'.\ s'.\ e'}{t.\ s.\ e}$, where t', s' and e' represent the records in trials, time and errors respectively of the control groups on Section I, II, III, or IV and t, s and e the corresponding records for the entire maze. Such a formula may weight to an unfair degree certain of the learning criteria. But it is far from being decided which criterion is the best, so the writer is inclined to utilize them all in one formula. If these criteria varied directly, such a formula would not be needed.

The records used are listed in Tables I, VI and X for the rats and Tables III, VI and XI for the humans. The records for the learning of the problem as a whole are those where

no more retracing was allowed than normally occurs in the learning of the separate parts ('whole' method with returns prevented).[1] For Section I the records of the 'part' learners are used. Control groups furnish the records for the remaining sections.

The results of the formulaic estimations are decidedly significant. For the rats it is found that 15, 1, 3 and 2 percent of the learning energy expended upon the entire maze is required to master units I, II, III and IV respectively. With the humans, the results are 4, 6, 1 and 11 percent. As a final average, the rats score 5.25 percent, the humans 5.5 percent. It is clear that this value would be 25 percent, provided that learning effort varied directly with the length of material. The figures argue that mazes of porportionate difficulty and of one-fourth the length of a larger maze, require scarcely more than one-twentieth the learning effort needed to master the larger problem.[2] This generalization holds for both rats and humans.

[1] Chapter III brought out the logical necessity of making comparisons with these data rather than with the results where freedom of retracing into the return sections was allowed. Of course the time and error records are far higher under the non-restricted conditions.

[2] Ebbinghaus has shown that there is no direct relationship between the length of nonsense series and the learning effort required. He presents two tables of data (*Memory,* pp. 47-49, Columbia University Teachers College Educational Reprints No. 3), these being secured during two testing periods separated by an interval of three years. They have special value in showing not only that diminishing returns for the learning effort operate but also that this loss (due to excessive length of the material) is not fully eliminated when practice effect is developed to its maximum. This is shown by bringing together the original data into one table and starring the results from the first testing series.

Number of syllables in a series	Number of repetitions necessary for first errorless reproduction (exclusive of it)
7	1
10	13*
12	16.6
13	23*
16	30
16	32*
19	38*
24	44*
36	55

The periodic regularity in which these results distribute is marked. The

The significance of these results for the 'whole'-'part' problem is clear. It pays—other things being equal—to learn a complex motor problem by easy stages. Otherwise, diminishing returns for the energy expenditure are secured. The causes of this need not be sought here, although they are probably inherent in the conditions of transfer discussed in the present chapter. Irrespective of causes, the facts of energy expenditure function well in explaining the results of 'modified part' procedure. The advantage of learning by easy stages, taken in conjunction with transfer conditions and the progressive elimination of the positional factors set up in 'part' learning, go a long way not only toward explaining the superiority of the 'modified part' methods over the 'whole' method, but also toward pointing out the inherent advantages of any 'part' procedure. There are probably other explanatory factors that have not been suggested. The above are not meant to be exhaustive. They do represent to the writer, however, the only explanations he can now set forward to meet a novel and exceedingly interesting experimental finding.

The following summary lists the important developments of the chapter:

(1) Transfer factors operate at their full value in 'part' procedure.

(2) This transfer is general and specific. The important general items are a general maze habit, consciousness of power, and favorable emotional tone. The specific items refer to the details of the maze pattern.

(3) Transfer fails to render the final areas of a complex motor problem more easily mastered. 'Part' procedure reverses these conditions.

(4) Learning effort does not vary directly with the length

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chief significance of these results for the present research rests, however, upon the fact that they, taken in conjunction with the results of the present research, make it possible to state that the law of diminishing returns operates (a) in the mental field, (b) for the learning of motor and verbal material, (c) for humans and animals, and (d) irrespective of earlier practice, though this is contradicted by Meumann.

of material. Diminishing returns are secured as the material is lengthened.

(5) The inherent advantages of 'part' learning are mainly the complete utilization of the transfer items and the avoidance of diminishing returns due to the excessive length of the motor problem.

(6) The inherent advantages of 'part' learning, together with the elimination of place associations, explain the universal superiority of 'modified part' methods in motor learning.

CHAPTER VII

Massed vs. Distributed Effort in 'Whole' and 'Part' Learning

The relation of the distribution of learning effort to the 'whole'-'part' discussion is obvious. Nothing totally new is being injected into the research. Heretofore the writer has considered the 'whole' and 'part' methods when two trials were allowed per day. Limiting the number of trials per day is necessary when rats are being employed for the experimentation. Consequently, the same time relationships had to be maintained for the humans, otherwise no comparative statements could be made. Under these defined learning conditions, it has been shown that the 'whole' method of learning is superior to the 'part' method but that the bad aspects of the 'part' method can be so eliminated as to produce 'modified part' methods far superior to the original 'whole' method. These generalizations have been shown to hold for both rats and humans. But it is obvious that no comparison can be made with any previous work on humans, where verbal material was used. Massed effort has always been used in the 'whole'-'part' testing, whether the learning was nonsense material, prose or poetry. Hence, the writer desires to find whether the relative value of the 'whole' vs. the 'part' methods depended to any degree upon massing or distributing the learning effort. With maze results established for massed learning conditions, comparisons might then be made with the verbal results.

The experimental literature contains numerous references to the value of distributed effort in motor learning. Browning, Brown and Washburn (2) early showed that such distribution was favorable. Murphy (12) has just published his results for javelin throwing. His conclusions are based upon the records of groups practicing one, three or five times per week. He is inclined to generalize for rote and logical learning as well as

for motor. "Better work, for the amount of time expended, can be done in our schools (both for hand manipulations and also so-called mental work), through a distribution of three times per week than through a distribution of five times per week." Ulrich showed that rats learned the maze with fewer trials when effort was distributed to trials every third day. No human maze experimentation has been published. No comparative experimentation has been done with rats and humans to test out the respective value of massed vs. distributed effort.[1] So far as regards the 'whole' and 'part' methods in relation to the distribution question, the literature shows that the matter has never been treated. The present chapter is concerned with this problem.

Six new groups of humans were secured. Each group included six subjects. Each group was taught Maze A by one of the methods described in earlier chapters. These in order were as follows: 'Whole', with returns allowed, 'whole', with returns prevented, 'total part', 'progressive part', 'direct repetitive', and 'reversed repetitive." Preliminary instructions, methods of data gathering, etc., were the same as in previous experiments. The sole difference was that no time was allowed to elapse between trials.[2] As soon as a run was completed, the subject was given subsequent trials, with no time for rest, conversation, removal of the hand from the maze area, etc. Continuous attack upon the learning problem was absolutely secured.

The behavior of these groups merits some comment. The

[1] Obviously, a problem would need to be relatively simple to permit mastery by the rat in successive trials. The initial emotional complex, constant distractive tendencies, etc., render massed tuition extremely difficult. However, with a simple problem, thorough preliminary training, utilization of hunger, sex and other stimuli, the rat may be taught a motor problem without the customary time interval. At least the learning could be concentrated within a few hours.

[2] Perrin's recent comparative work on adult and child maze learning allowed "all the time between trials they desired for rest, physical and mental recreation." Such is no doubt needed with the children. It is a question, however, whether conclusions may justly be drawn between individual children or between children and adults if the time interval is not constant as to length.

group learning the maze as a whole and with no prevention of returns attacked the problem well. After a few trials, improvement ceased and the learning act became very trying. A long period of almost random activity, hurried yet purposeless exploring ensued. Each student showed signs of nervousness when the first dozen trials failed to bring success. To this excitability the men were even more susceptible than the women. As each successive trial continued to bring errors, the run became more hurried, jerky and erratic. Generally the student reached a stage in his learning where he knitted his brow, closed his eyes, checked his speed and settled down to a slow, laborious process of eliminating certain specific errors per trial. The period of high tension remained and the completion of the final successful runs always brought unmistakable relief. The 'whole' method with returns prevented produced behavior such as the above, yet this was to a lesser degree. Without exception, the 'part' methods *failed* to arouse a strong emotional tone or to cause nervous excitement. The attack upon the problem was always steady, irrespective of the method employed. The act of connection in 'part' learning was singularly free from confusion, this being a very marked departure from the behavior so characteristic of both humans and rats when learning was broken by the twenty-four hour interim. The data of these experiments in massed effort are compared with those of the humans when effort is distributed in Table XXI. In Table XXII is found the percentage of advantage or disadvantage obtained by massing effort. The table is complete for trials, time, and errors of the various types. See pages 77, 78.

In agreement with the previous conclusions, massing the learning effort is highly unfavorable for certain methods. It increases the number of trials, the learning time, and all types of errors when the 'whole' method of learning is used. This is true irrespective of the prevention of returns and applies to all measuring criteria. Without exception there is a marked percentage of gain when distribution occurs. This is true also for two 'part' methods—the 'direct repetitive' and the most efficient for all human and animal learning under distributive

conditions, namely the 'progressive part'. The advantage is, however, less marked than for 'whole' method learning. In some items of comparison, the absolute differences are almost negligible. Significant changes occur so far as the total 'part' method and the 'reversed repetitive' are concerned. By all measuring criteria, the 'part' method gains over distributive results and the same is true for the 'reversed repetitive' (with slight and unimportant exceptions for this latter.)

But the significant results are not so much in reference to the comparison of the same method under these changed temporal conditions as to the important fact that each 'part' method shows superior (by all criteria of measurement) to either type of 'whole' method, thus altering very markedly the 'whole'-'part' results set forward in earlier chapters. Furthermore, the total 'part' method (so unsuccessful under distributive conditions) under massed conditions becomes not only better but almost the best of all available methods. It is even slightly more efficient than the universally superior 'progressive part' in point of trials but slightly weaker in time and considerably so in total errors. Consequently it is considered second in advantages. *But its rise in the efficiency scale under these massed conditions is unmistakable.* Its great gain consisted not so much in the learning of the four units but in the connecting act. For Section I the total error record was greater than in the distributed case, the remaining three being almost identical. (24, 12; 10, 9; 5, 4; 7, 5 for I, II, III, IV respectively). The change of results for the 'part' method are so marked that a full comparison of the data is made in Table XXIII. The difference in scores is especially obvious in the I-IV act of connection. See page 78.

It is evident that explanation is needed for these massed effort results. It needs to be shown why each type of 'part' learning is superior to that of the 'whole'. These results are not only opposed to those secured under distributive conditions but exactly contradictory to the ones commonly accepted for verbal learning. In the latter, learning effort is always massed, yet herein have the results always been in favor of the 'whole' method procedure. The writer can do little more than speculate.

Until the problem of massed effort is understood and its relationship not only to distributed effort but also to different types of problems established, final conclusions directed towards the 'whole'-'part' procedure are impossible. Each is a separate problem, yet each depends upon and illuminates the other.

Learning of the maze problem passes through two distinct stages. (a) *Elimination.* The subject, after getting acquainted with the general character of the maze, settles down to the arduous task of eliminating all types of errors. The enormous time expenditure and the great number of errors made during the first half of the tuition period point out the difficulty of this learning act. Increasing complexity of the maze brings increasing demands upon the subject. These specific demands have been commented upon at length in earlier chapters. Now, with massed effort the confusion is cumulative from trial to trial. In place of the errors being gradually eliminated, instability is generated. Through this period there is little chance that the needless movements of one trial will fail to appear in the ones directly following. Even their disappearance for one trial argues little for their permanent loss. It is during this stage of discovery and elimination that distributed effort has its place. The many useless movements tend to fall away from the success-bringing series, while the latter seems to affect the serial bonds during the interim of inactivity. With rats and humans, the measured improvement is, from day to day, too commonplace to warrant comment.

(b) *Mechanization.* Logically following the preceding but chronologically inseparable from its final stages, is the period where the subject is *hammering in* the final, sensori-motor coordinations. Tendencies to enter cul de sacs, to retrace, etc., are still present but these are swamped in the rapid, forward-going activity. The function of this period is to render definite the elimination of these errors and to increase the speed of the run. Exploration has now no place. The activity is well on its road to the habitual level. Its momentum is its major guarantee of success. This is the time for massed effort. By successive repetitions of the successful runs, the tendencies to error

become less and less liable to function, as the fixation proceeds rapidly and surely. In a strictly psychological sense, the subject who hesitates is lost. He can now drive out of the series the danger-giving elements and so render their elimination permanent. In distributing his effort, such permanent elimination is certainly less slow in attainment. Efficiency demands massing of the learning.

The principles of elimination and mechanization have immediate applicability to the 'whole'-'part' learning problem. They show at once, no doubt, why any form of the 'part' method is superior to the 'whole' under massed conditions. The parts as such were always simple. Hence, the need for distribution of learning effort was reduced to a minimum. (It seems logical that distributive and massed efforts should be equally efficient for simple mazes. This needs to be shown experimentally). However, even in our simple I-IV sections, there was slight advantage with distribution. (See figures, p. 62.) The act of connection demanded speedy, non-exploring, rapidly succeeding attacks. Massing the effort provided this, hence making all the 'part' methods highly efficient. With the 'whole' methods there was no opportunity for the great number of useless movements to disappear automatically during the time interval. Rather, they remained to mar the runs, to delay final success, and increase the nervousness of the subject. Only by the greatest effort were they finally eliminated. If the subject had been able to break up the task of error learning into simple, easily mastered units, to eliminate errors and mechanize each unit, and to expend his best energies in rapid attacks at connection, success would have been far more quickly attained.

It appears, therefore, that reliance upon massed or distributed effort depends somewhat upon three fundamental factors. (1) *Difficulty of the problem.* The problem with many possibilities of error needs distributive handling. This need decreases with decreasing difficulty of the problem. (2) *Stage of the learning.* In the discovery and eliminating stages, distribution is essential. In the stage of strenuous mechanization, massing of effort is advisable. (3) *Method of learning.* The 'whole' method re-

quires distribution for easy mastery, the 'part' methods may require distribution for mastery of the units but massing for connection. Under massed conditions the 'part' methods are always more efficient.

These principles seem fundamental for the human pencil maze situation. They may need expansion or qualification. They are put forward as suggestive and with the hope that experimentation may be directed toward a problem regarding which there is practically no knowledge. It may be that the results for learning verbal material under massed and distributed conditions must be recanvassed. It is clear that one or more of four conditions must maintain. (1) The conclusions of the writer are not truly descriptive of the specific motor problem discussed. (2) These results, though true for the maze, are not general for the entire motor field of learning. (3) The results in verbal learning (for all types of material) need reconsideration. (4) There are no correlations to be drawn between learning upon the motor and ideational levels. The writer cannot agree to the accuracy of (1). He is inclined to argue from his results to the general motor field (2). Any opinion regarding (3) and (4) is sheer speculation, whose validity must rest upon experimental results.

The results of this investigation of the distribution of learning effort in relation to the 'whole' and 'part' methods of learning may be summarized as follows:

(1) Massing the learning effort is highly unfavorable for 'whole' method learning. This is in agreement with the accepted results in the experimental field.

(2) The pure 'part' method proves much more efficient than when effort is distributed.

(3) All types of 'part' methods produce better learning results under massed conditions than do the 'whole' methods. This superiority is demonstrated by all measuring criteria.

(4) The superiority of the 'part' methods are probably statable in terms of the eliminative and mechanizing aspects of the learning period.

(5) Reliance upon massed or distributive effort depends upon

a number of fundamental factors. Chief of these are the difficulty of the problem, the stage of the learning, and the method of learning.

(6) Learning a motor problem by 'part' methods produces results that contradict the findings secured under like massed conditions with rote and logical material.

(7) The full significance of the distribution of the learning effort is far from being known.

CHAPTER VIII.

Comparison and Summary

The conclusions of this experiment have been cumulative. They have been discussed at length in the body of the paper at their point of emergence. It is here merely in order to state the final conclusions regarding the propositions formulated in Chapter I.

I. Efficiency of various 'whole'-'part' learning methods in the motor situation.

a. The 'whole' method with returns prevented is more efficient than with returns allowed.

b. The 'whole' method is far more advantageous than the 'part' method.

c. The 'whole' method is decidedly less favorable than the 'progressive part' and 'direct repetitive' part methods. With the rats, the 'reversed repetitive' part methods. is also more efficient. Failure for this to prove so with the human is due to the inability of the kinaesthetic cue to function as the recognitive agent.

d. The weaknesses of the 'part' method are not due to negative transfer in the learning of the motor units, disintegration through time, retro-active inhibition, contiguity of unit functioning, nor unit incompatibility in a larger series. The weaknesses are due to failure in the act of connection, the conditioning factors being traced to the positional aspects of the temporal and spatial series.

e. 'Part' procedure possesses certain inherent advantages. These are mainly the complete utilization of the transfer items and the avoidance of diminishing returns due to the excessive length of the motor problem.

f. The strength of all types of improved ('modified') part methods rests upon the progressive elimination and distributive handling of the emotional and positional factors, together with the inherent advantages of any 'part' procedure.

II. Universality of various 'whole'-'part' learning methods in the motor situation.

a. Improvement of 'whole' method learning universally follows when returns are prevented.
b. The pure 'part' method is universally inferior to the 'whole' method.
c. The 'progressive part' and 'direct repetitive' methods are universally far more advantageous than the 'whole' method. The 'reversed repetitive' method fails to attain like universality, owing to the recognitive inefficiency of kinaesthesis in the human. In general, however, almost any type of 'modified part' method is universally to be preferred.
d. For all methods the correlations between the various learning criteria of trials, time and errors are universally high. No royal road in motor learning is open to the human and denied to the rat. Certain changes in position for certain methods render a cross correlation less marked. These shifts are traceable to differences in the retracing tendency and the recognitive capacity. They do not vitiate the comparative results listed in a-c above.
e. The pure 'part' and 'modified part' methods become increasingly superior to the 'whole' method when learning effort is massed rather than distributed.

III. Comparison of motor learning and learning verbatim.

(1) Comparison of methods.

a. The 'whole' method with returns allowed is the N-Verfahren or "natural" method (Steffens).
b. The 'whole' method with returns prevented is the G-Verfahren (Steffens), Das Lesen im ganzen (Ephrussi), Lernen im ganzen (Pentschew, Meumann, etc.), Methode globale (Larguier des Bancels) and the standardized 'whole' procedure of the English investigators (Lakenan, Pyle and Snyder, etc).
c. The pure 'part' method is the second S-Verfahren (Steffens), Das Lesen mit gehaüften Wiederholungen (Ephrussi), Lernen in Gruppen (Pentschew), Methode fragmentaire (Larguier des Bancels) and the 'part' method of the English experimentation (Lakenan, etc).
d. The 'progressive part' method resembles to a slight degree the second part method of Pyle and Snyder.
e. The 'direct repetitive' method resembles to a slight degree the first S-Verfahren (Steffens). The 'reversed repetitive' method finds no method comparable to it.
f. The 'elaborative part' method resembles to a slight degree the first part method of Pyle and Snyder.

g. No motor method employed is comparable to the Lernen im gebrochenen ganzen (Pentschew).

(2) Comparison of results in motor learning and learning verbatim.

a. The 'whole' method with returns allowed agrees with the "natural" method in learning verbatim as being very inefficient.

b. The 'whole' method with returns prevented agrees with the 'whole' method in learning verbatim as being superior to the "natural" method and the pure 'part' method, (waiving the single exception of Ephrussi's conclusions for learning nonsensical material by the 'part' method).

c. The 'progressive part', the 'elaborative part', and the 'repetitive part' methods, though proving superior to the 'whole' method in motor learning, fail to do so in learning verbatim. However, these motor methods have not been strictly duplicated in learning verbatim (either with rote or logical material), so an exact comparison is unwarranted.

e. The several favorable modifications of the 'part' method as employed in motor learning, need to be tested in learning verbatim. Until such be done, it seems unwarranted to argue that all types of 'part' methods are inferior to the 'whole' method for the learning of rote and logical material.

IV. Relation of the conculsions to practical schoolroom activities of the motor type.

a. The complex motor problem is probably always best mastered by one of the several 'modified part' methods. The one universally to be preferred is the 'progressive part'.

b. Distribution of the learning effort is of value for the 'whole' method but not for the 'part' procedure.

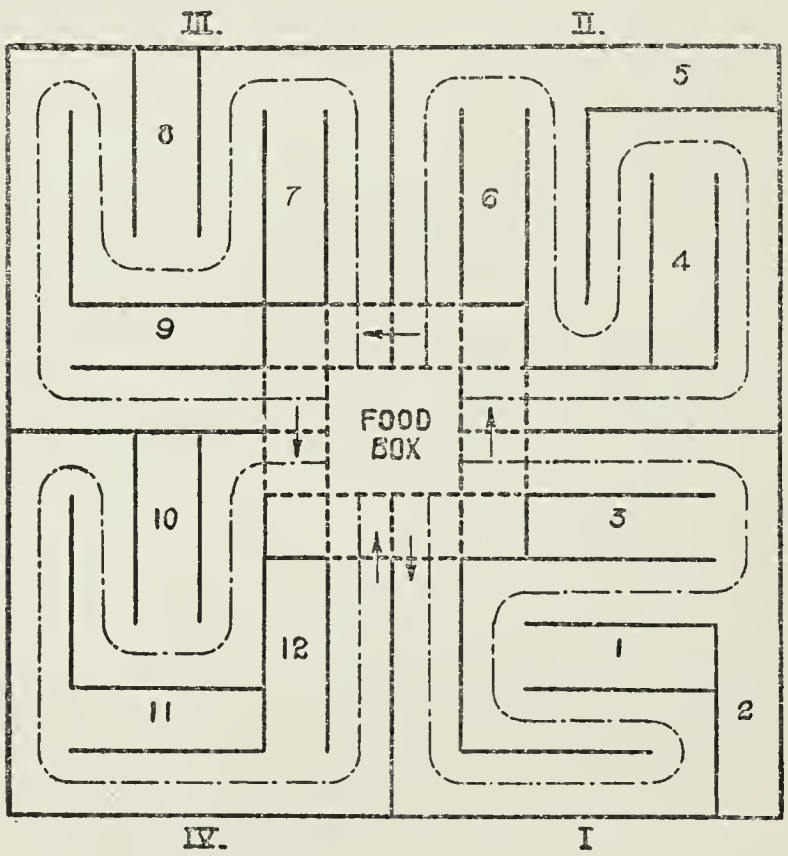
c. Distribution of the learning effort is of value for the exploring and eliminative stages of learning, not for the rapid mechanizing stage. Here effort should be massed.

d. When the conditions of learning call for a massing of learning effort, the 'whole' method becomes increasingly inefficient with increase in problem complexity, the 'part' methods increasingly more efficient.

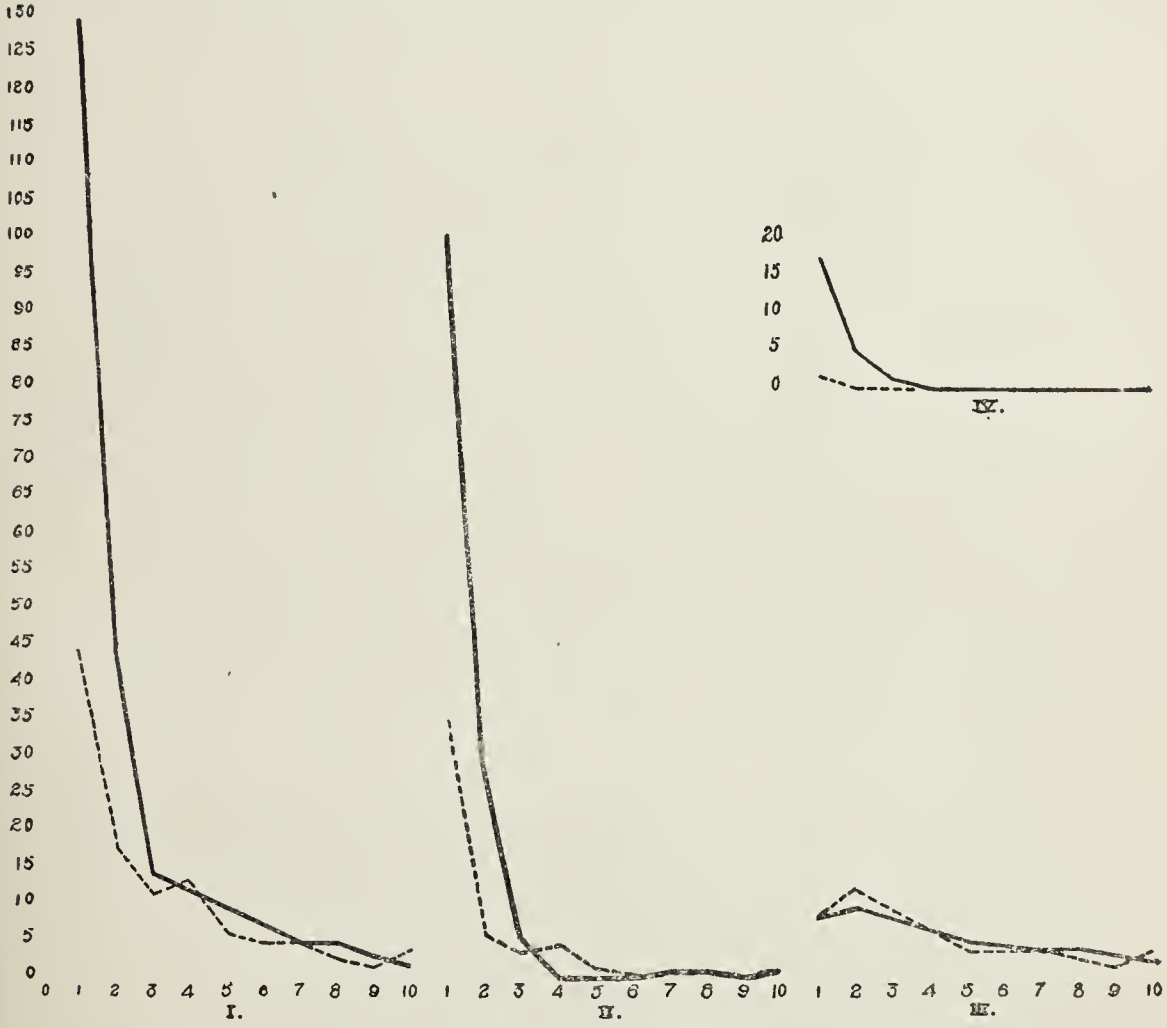
e. The conclusions drawn apply solely to the motor type of learning, though they suggest that the rote and logical types need additional experimentation.

APPENDIX

Figure 1. Maze A. Roman numerals refer to the four independent sections of the maze. Dotted division lines indicate the entrances and exits for the different sections into the food-box. Also, they designate the removable panels. The running dotted lines show the true pathway for each section. The arrows between sections point out the continuous pathway when the maze is being learned as a whole or in the connection of the separately learned units. The vertical arrows indicate the main entrance and exit. Arabic numerals designate the cul de sacs. Slides for the prevention of returns occur after cul de sacs numbered 3, 6, 9, 12.



Graphs I-IV. To show graphically the learning curves of two rat groups in learning Maze A with and without the prevention of returns. The unrestricted group had 12 rats, the restricted 9. The former is represented by the solid line, the latter by the dotted. No. I is the total error curve; no. II for the retraces (Type C); no. III for the forward cul de sacs (Type A); no. IV for the retrace cul de sacs (Type B). See Table VI. (The learning is divided into ten equal stages as based on the number of trials and the errors of each tenth of the learning computed. See the method of Vincent, The Function of the Vibrissae in the Behavior of the White Rat, Behavior Mon., 1, 5, 1912, pp. 15-17.)



	Trials	Time	Errors			
			A	B	C	Total
I	34	470″	37	2	13	52
II	2	33	1	0	2	3
III	14	127	9	0	5	14
IV	9	111	8	0	3	11
I-IV	15	1166	19	15	85	119
Total	30	1907″	74	17	108	199

Table I. A table to show the average number of trials, time and errors of nine rats in learning Maze A by the 'part' method. In estimating the total number of runs, each sectional run is arbitrarily counted as one-fourth of a complete run.

	Trials	Time	Errors			
			A	B	C	Total
Whole	27	4174″	54	24	139	217
Part	30	1907″	74	17	108	199

Table II. A table to compare the average number of trials, time and errors of two rat groups learning Maze A by the 'whole' and 'part' methods respectively.

	Trials	Time	Errors			
			A	B	C	Total
I	6	198″	4	0	20	24
II	3	47	3	2	5	10
III	2	49	1	0	4	5
IV	1	25	1	1	5	7
I-IV	20	901	28	22	141	191
Total	23	1220″	37	25	175	237

Table III. A table to show the average number of trials, time and errors of seven humans in learning Maze A by the 'part' method.

	Trials	Time	Errors			
			A	B	C	Total
Whole	12	641″	16	13	97	126
Part	23	1220″	37	25	175	237

Table IV. A table to compare the average number of trials, time and errors of two human groups, learning Maze A by the 'whole' and 'part' methods respectively.

	Trials	Time	Errors			
			A	B	C	Total
Rats						
Whole	27	4174″	54	24	139	217
Part	30	1907	74	17	108	199
Humans						
Whole	12	641	16	13	97	126
Part	23	1220	37	25	175	237

Table V. A table to compare the averages of rats and humans in 'whole' vs. 'part' learning. These data are extracted from Tables I-IV.

	Trials	Time	Errors			
			A	B	C	Total
Rats						
Allowed	27	4174″	54	24	139	217
Prevented	30	1666	56	4	51	111
Humans						
Allowed	12	641	16	13	97	126
Prevented	17	541	23	6	51	81

Table VI. A table to compare the average number of trials, time and errors of rat and human groups, learning a motor problem (Maze A) as a whole, with returns allowed and prevented.

	Trials	Time	Errors		
			A and B	C	Total
Allowed	50	2886″	188	124	312
Prevented	50	1813″	151	53	204

Table VII. A table to show the average number of trials, time and errors of two rat groups given fifty trials upon Maze B, with and without the prevention of returns.

	Percentage of Group	Trials	Time	Errors			
				A	B	C	Total
Rats							
Allowed	64	36″	2676	155		119	274
Prevented	54	33	1818	116		55	171
Humans							
Allowed	100	33	2599	101	155	407	663
Prevented	100	51	2669	130	130	388	648

Table VIII. A table to show the average learning record of rat and human groups upon Maze B with and without the prevention of returns.

	Trials	Time	Errors			
			A	B	C	Total
Rats						
Whole	30	1666″	56	4	51	111
Part	30	1907	74	17	108	199
Humans						
Whole	17	541	23	6	51	81
Part	23	1220	37	25	175	237

Table IX. A table to compare the average number of trials, time and errors of rat and human groups, learning Maze A by the 'whole-prevented' and 'part' methods.

		Trials	Time	Errors			
				A	B	C	Total
Sec. II	Control Group	8	128″	6	1	6	13
	Part Learners	2	32	1	0	2	3
Sec. III	Control Group	20	254	19	2	14	35
	Part Learners	14	127	9	0	5	14
Sec. IV	Control Group	9.25	316	7	2	21	30
	Part Learners	9	111	8	0	3	11

Table X. A table to compare the average learning of rat groups upon a single maze (control group) with the averages for the group having previously learned one or more mazes (Part Learners).

		Trials	Time	Errors			
				A	B	C	Total
Sec. II	Control Group	5	132″	2	2	7	11
	Part Learners	3	47	3	2	5	10
Sec. III	Control Group	8	183	7	6	19	32
	Part Learners	2	49	1	0	4	5
Sec. IV	Control Group	10	254	4	4	43	51
	Part Learners	1	25	1	1	5	7

Table XI. As for Table X, human learning.

	Trials	Time	Errors			
			A	B	C	Total
I	.4	2.5″	.4	0	0	.4
II	0	0	0	0	0	0
III	2	13.4	1	.2	1	2.2
IV	0	0	0	0	0	0
Average	.6	3.9″	.35	.05	.25	.65

Table XII. A table to show the average relearning effort of a group of rats having been taught subsequent motor habits after mastering earlier ones. The data are indicative of retro-active inhibition.

	Trials	Time	Errors			
			A	B	C	Total
I & III	.2	6.3″	0	.1	1	1.1
I-IV	0	0	0	0	0	0
II & IV	.3	5.3	.33	0	0	.33
I-IV	0	0	0	0	0	0
IV & I	4	10	.2	.3	1.5	2

Table XIII. A table to show the average records of a rat group in the elimination and subsequent reconstruction of specific motor units learned as parts of a larger motor situation (Maze A).

	Trials	Time	Errors			
			A	B	C	Total
1 & III	2	12″	1.25	0	.5	1.75
I-IV	0	0	0	0	0	0
II & IV	.5	3″	.50	0	.25	.75
I-IV	1	24″	.5	.25	.5	1.25
IV & I	.5	10″	.25	0	1.5	1.75

Table XIV. As for Table XIII, human group record.

	Time Interval	Trials	Time	Errors			
				A	B	C	Total
I	15 Days	.17	1″	.17	0	0	.17
II	8 Days	1	7	1.33	0	.5	1.83
III	5 Days	.17	.67	.17	0	0	.17
Average	9.33 Days	.45	2.89	.56	0	.17	.72

Table XV. A table to show the disintegration through time of the control upon the various maze sections as mastered in part learning, based on the average for six rats.

	Time Interval	Trials	Time	Errors			
				A	B	C	Total
I	13 Days	0	0	0	0	0	0
II	8 Days	1.5	9.3″	.83	0	0	.83
III	5 Days	1.3	10.1	1	0	1	2
Average	8.67 Days	.93	6.5	.61	0	.3	.94

Table XVI. As for Table XV, human group records.

Method	No. of Rats	Trials	Time	Errors			
				A	B	C	Total
Progressive Part	9	11	662″	39	2	24	65
Reversed Repetitive	8	17	882″	22	5	49	76
Direct Repetitive	11	21	1442″	45	9	88	142
Whole Returns Prevented	9	30	1666″	56	4	51	111
Total Part	9	30	1907″	74	17	108	199
Whole Returns Allowed	12	27	4174″	54	24	139	217

Table XVII. A table to show the average group records for the learning of Maze A by standard and original methods. In estimating total trials for these methods, each section traversed is counted quite arbitrarily as one-fourth a run. This probably weights the runs through the mastered sections but never in such a way as would produce more favorable comparisons with the 'whole' or pure 'part' methods. The methods are listed in their apparent order of merit, although the three measuring criteria do not always agree in arguing for this order.

Method	No. of Humans	Trials	Time	Errors			
				A	B	C	Total
Progressive Part	6	10	352″	10	3	44	57
Direct Repetitive	6	11	618	15	11	70	96
Whole Returns Allowed	6	12	641	16	13	97	126
Whole Returns Prevented	6	17	541	23	6	51	81
Reversed Repetitive	6	22	1014	27	24	175	226
Total Part	6	23	1220	36	25	176	237

Table XVIII. As for Table XVII, human learning.

Trials	Time	Errors			
		A	B	C	Total
1	41″	.4	.2	3.4	4
2	26″	.2	0	0	.2
3	33″	.4	0	0	.4
4	24″	0	0	0	0

Table XIX. A table to show the average time and errors per trial of six rats in connecting four sections, such connection having been preceded by an increasingly complex review of the various units. This is the nearest rat approach to massed learning effort.

	Trials and Time	Trials and Total Errors	Time and Total Errors	Trials and Type A Errors	Time and Type A Errors	Total and Type A Errors
Rats	.8705	.8325	.9451	.9269	.7750	.6775
Humans	.8325	.8325	1.0000	1.0000	.8325	.8325

	Trials	Time	Total Errors	Type A Errors
Rats and Humans	.6180	.3335	.3335	.4465

Table XX. A table to show the correlation between the learning criteria for all methods, both for rats and humans . Also, the correlation between the rat and human learning for all methods, correlation being measured by a single learning criterion. Ranking method $P=1-\frac{6\Sigma D^2}{n(n^2-1)}$

Method	Trials	Time	Errors			
			A	B	C	Total
Whole-Returns Allowed	30	1250″	41	27	192	260
	12	641	16	13	97	126
Whole-Returns Prevented	25	1208	40	14	150	204
	17	541	23	6	51	81
Total Part	10	538	15	9	83	107
	23	1220	36	25	176	237
Progressive Part	14	536	24	10	62	96
	10	352	10	3	44	57
Direct Repetitive	24	716	37	7	76	120
	11	618	15	11	70	96
Reversed Repetitive	20	764	29	10	87	126
	22	1014	27	24	175	226

Table XXI. A table to compare the average learning records of human groups for the various methods, with effort being massed and distributed. The results for massed effort always appear first.

	Trials	Time	Errors			
			A	B	C	Total
Whole-Returns Allowed	150	95	156	98	108	106
Whole-Returns Prevented	47	123	74	133	194	152
Total Part	−57	−56	−58	−56	−53	−55
Progressive Part	40	52	140	233	41	68
Direct Repetitive	118	16	147	−36	9	25
Reversed Repetitive	−9	−25	7	58	−62	−44

Table XXII. A table to show the percentage of advantage or disadvantage of massed in comparison with distributed effort.

Section	Trials	Time	Errors			
			A	B	C	Total
I	5.4	93″	2	2	8	12
	6	198	4	0	20	24
II	1.2	45	1	1	7	9
	3	47	3	2	5	10
III	2.4	28	3	0	1	4
	2	49	1	0	4	5
IV	2.4	28	1	0	4	5
	1	25	1	1	5	7
I-IV	7.6	344	8	6	64	78
	20	901	28	22	141	191
Total	10	538	15	9	84	108
	23	1220	37	25	175	237

Table XXIII. A table to compare the average learning records of human groups for the 'part' method, with effort being massed and distributed. The results for massed effort always appear first.

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